Saul Griffith.

CPUC, June 30, 2010

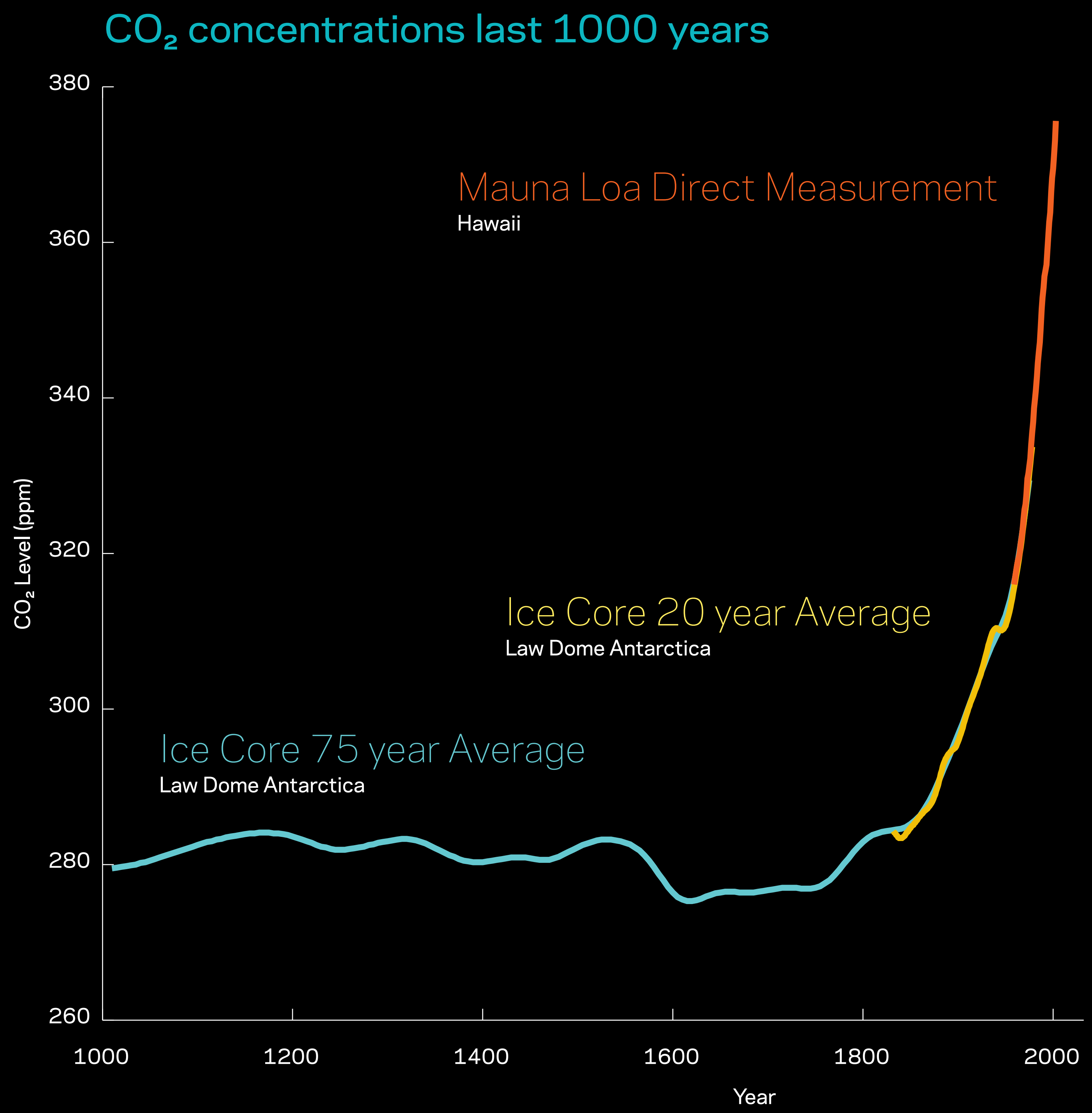
www.otherlab.com
www.wattzon.com
www.energyliteracy.com
www.makanipower.com
www.onyacycles.com

How do I think about the challenge?

Green by the numbers.

Two stories : one global, one personal.

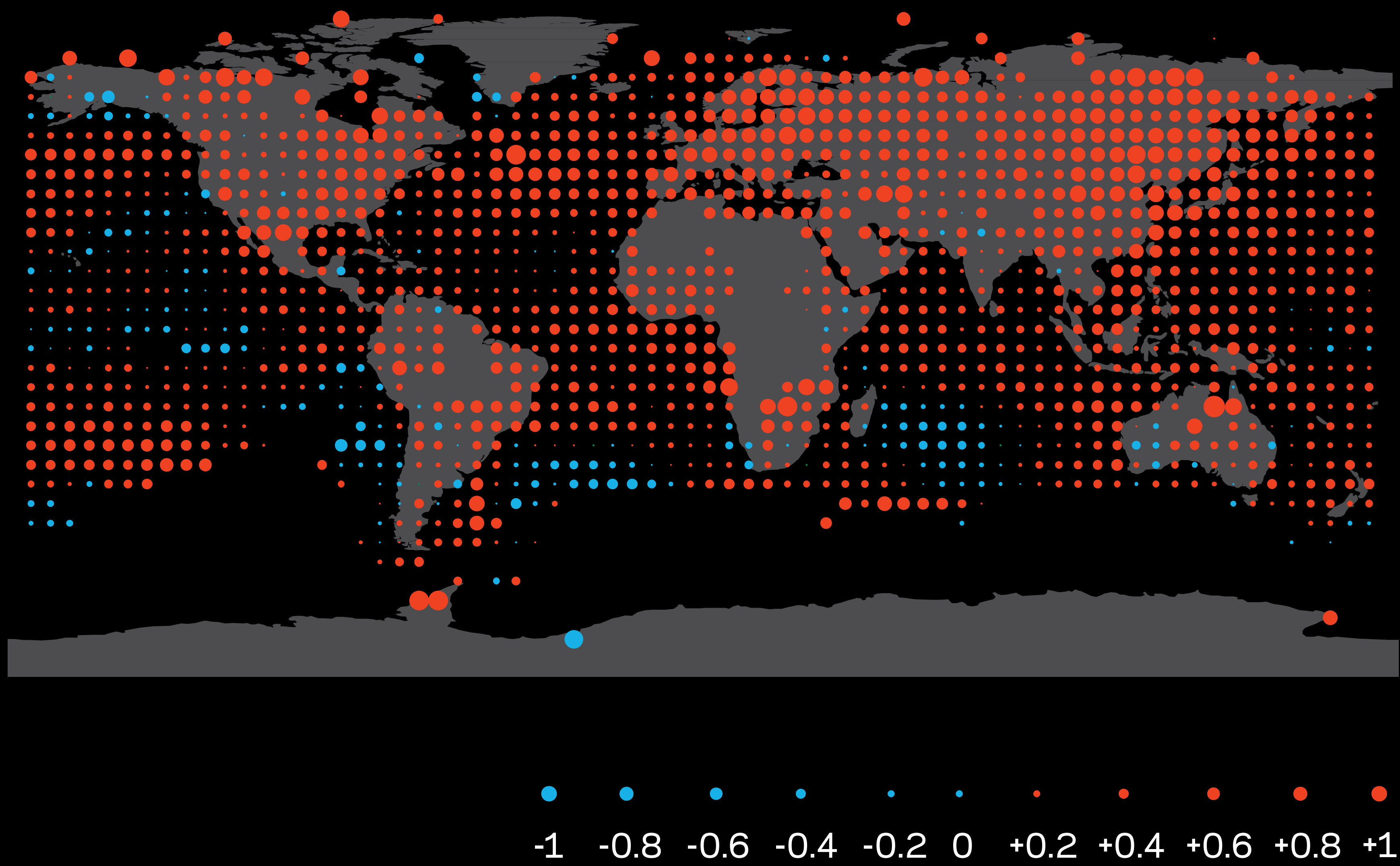
Supply : Generation



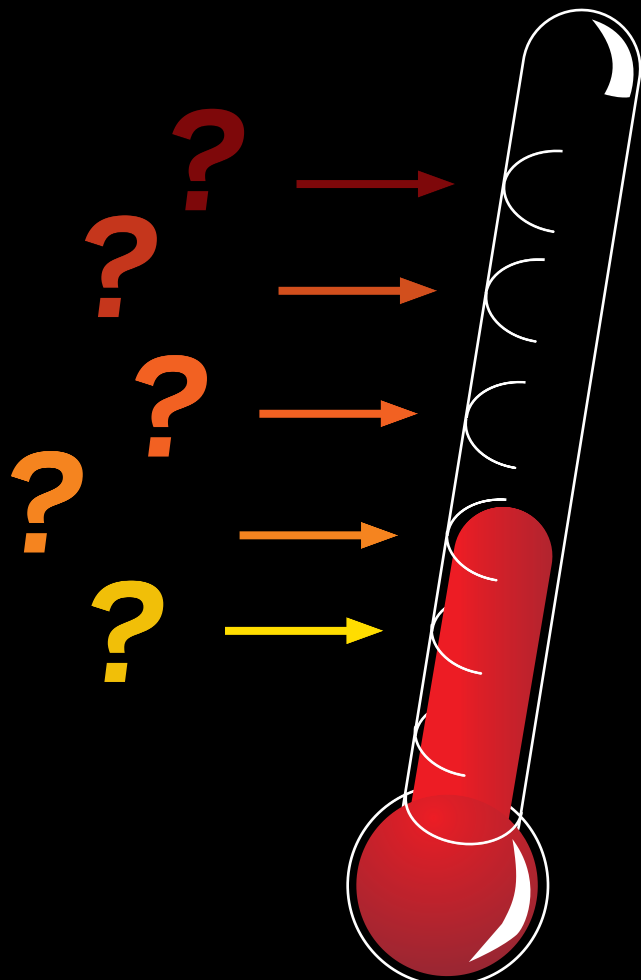
CO_2 concentrations last 1000 years
380
360
340
320
300
280
260
CO_2 Level (ppm)
Mauna Loa Direct Measurement
Hawaii
Ice Core 20 year Average
Law Dome Antarctica
Ice Core 75 year Average
Law Dome Antarctica
1000
1200
1400
1600
1800
2000
Year

Temperature Changes around the world in the last quarter of the 20th century

Trends in °C per decade



We need to commit to the temperature we want...



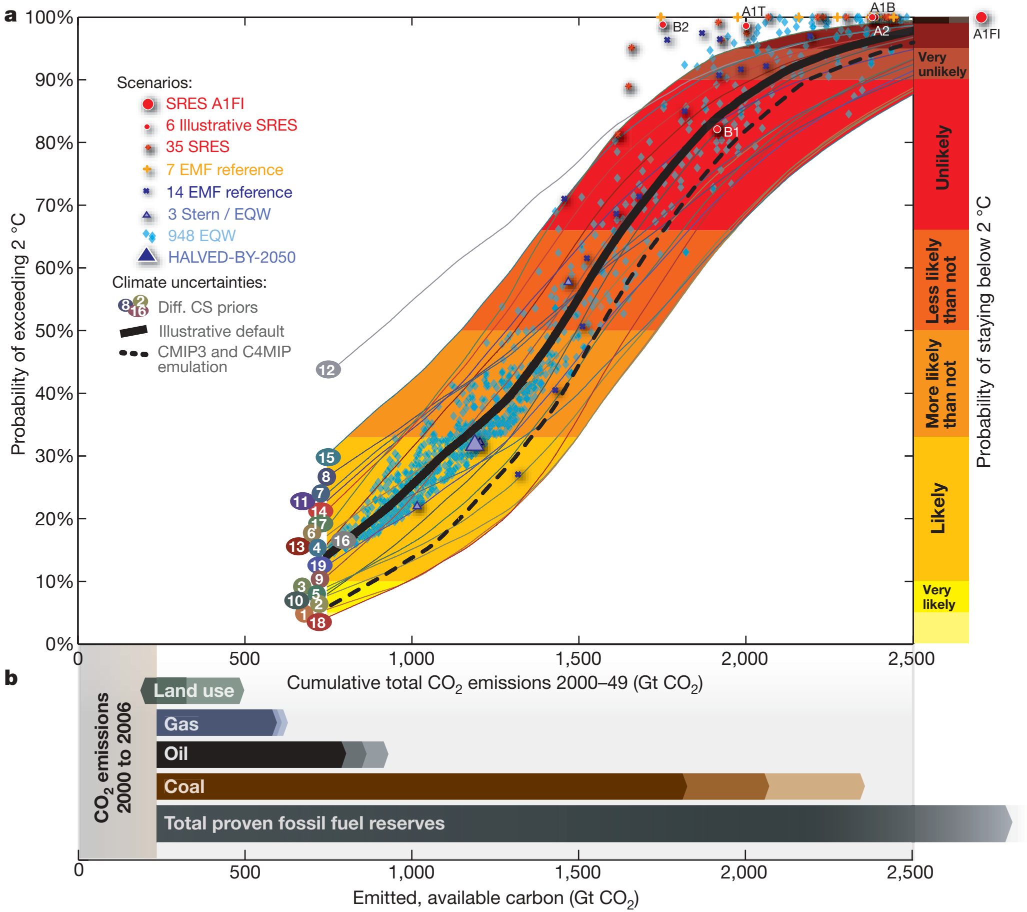
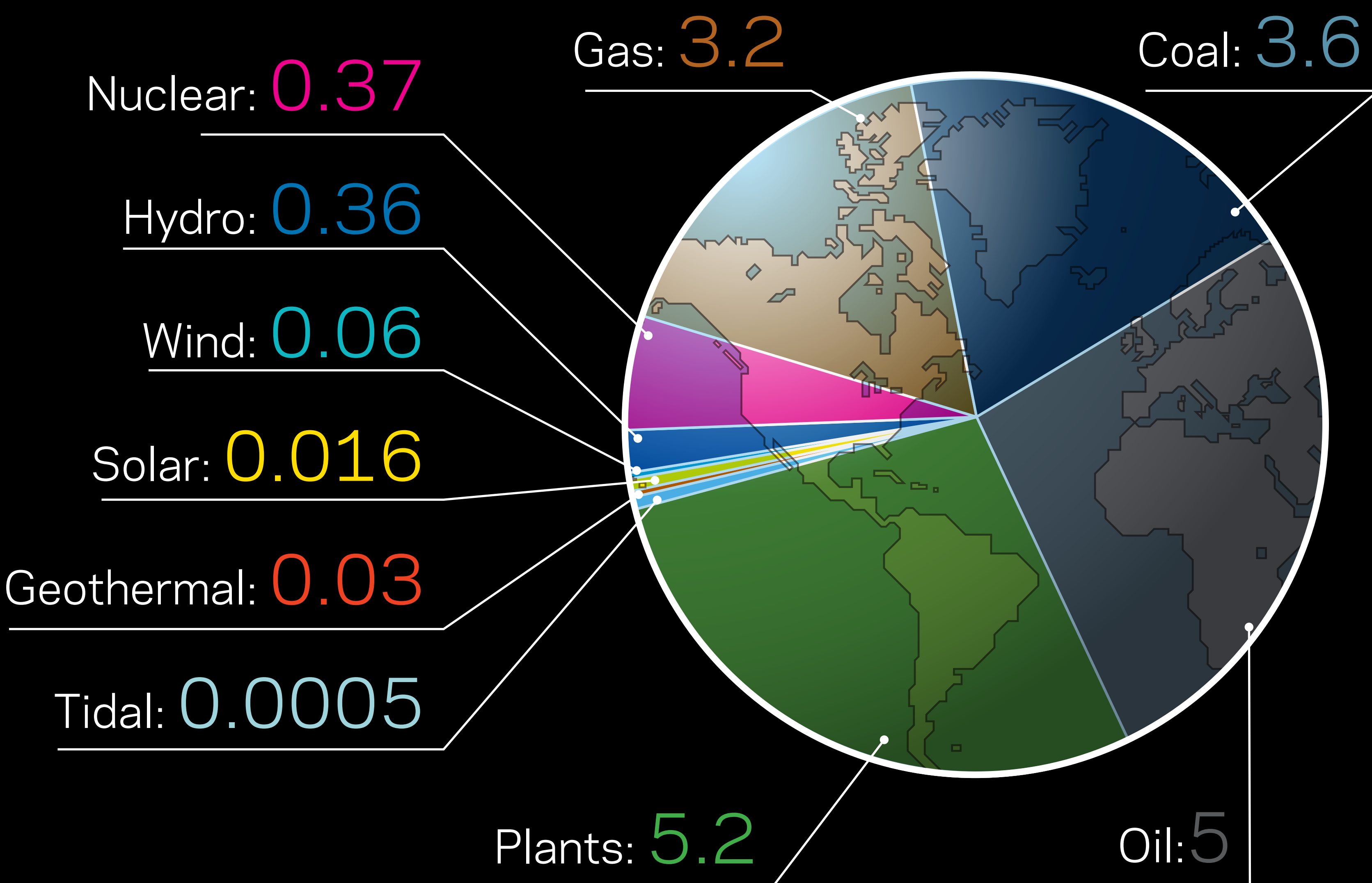


Figure 3 | The probability of exceeding 2 °C warming versus CO_2 emitted in the first half of the twenty-first century. **a**, Individual scenarios' probabilities of exceeding 2 °C for our illustrative default (dots; for example, for SRES B1, A2, Stern and other scenarios shown in Fig. 2) and smoothed (local linear regression smoother) probabilities for all climate sensitivity distributions (numbered lines, see Supplementary Information for data sources). The proportion of CMIP3 AOGCMs[26] and C4MIP carbon-cycle[8] model emulations exceeding 2 °C is shown as black dashed line. Coloured areas denote the range of probabilities (right) of staying below 2 °C in AR4 terminology, with the extreme upper distribution (12) being omitted. **b**, Total CO_2 emissions already emitted[3] between 2000 and 2006 (grey area) and those that could arise from burning available fossil fuel reserves, and from land use activities between 2006 and 2049 (median and 80% ranges, Methods).

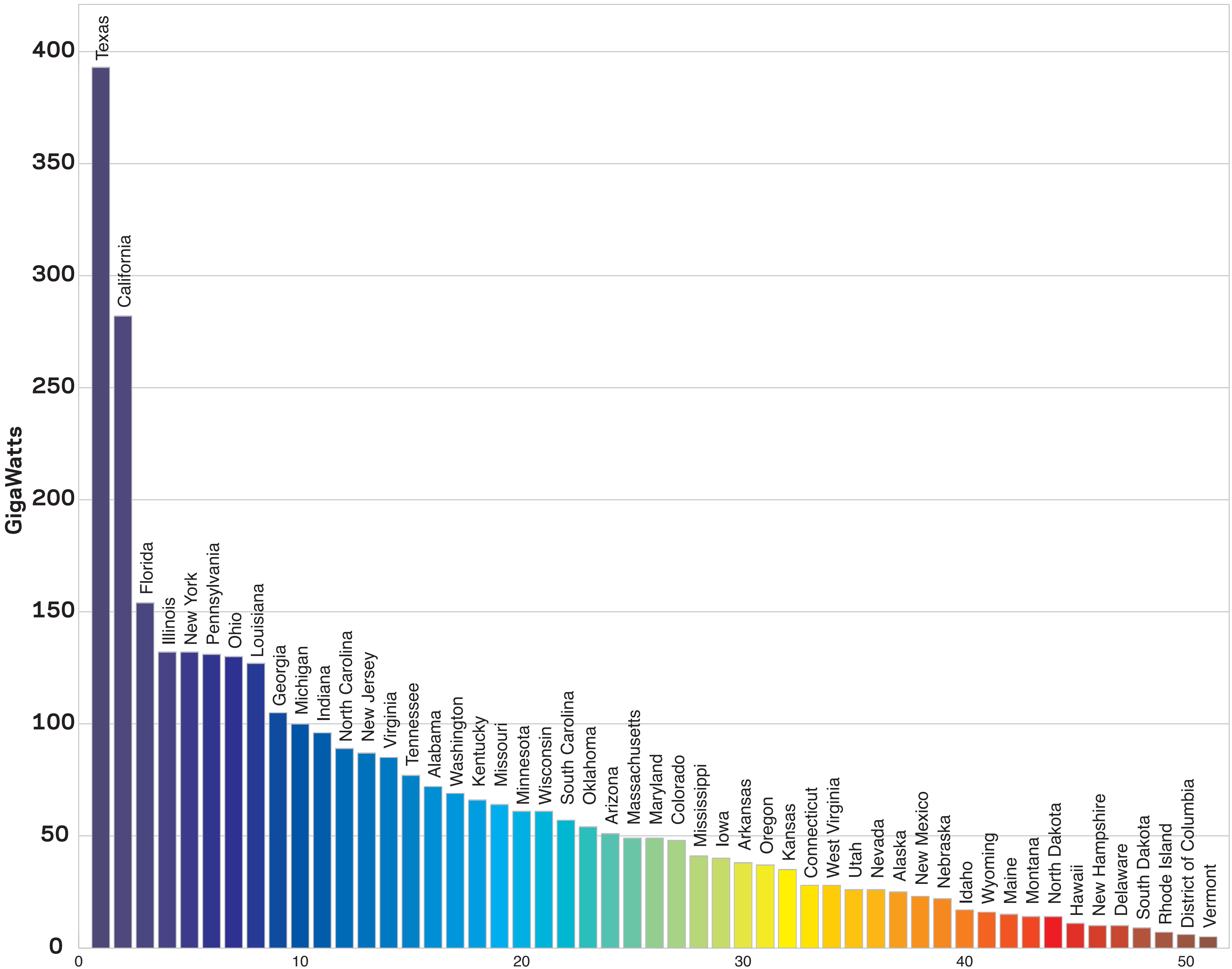
Energy production

Units shown in Terawatts (TW)

Humanity 18 TW



State-level energy consumption, 2006 (GW)



What is the challenge?

Current Demand:

16 TW (IEA)

Fossil Fuel:

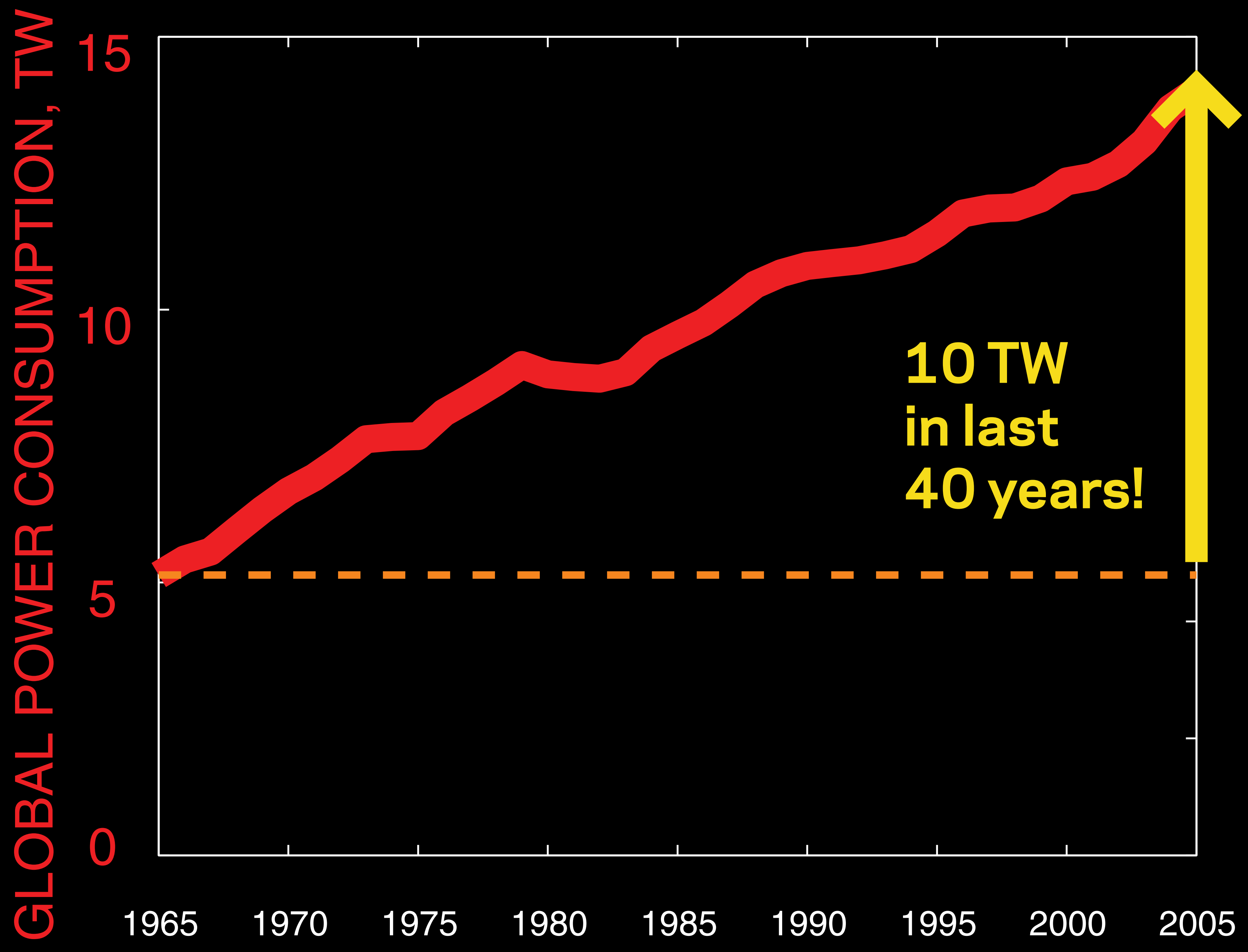
2-3 TW

Existing non-carbon:

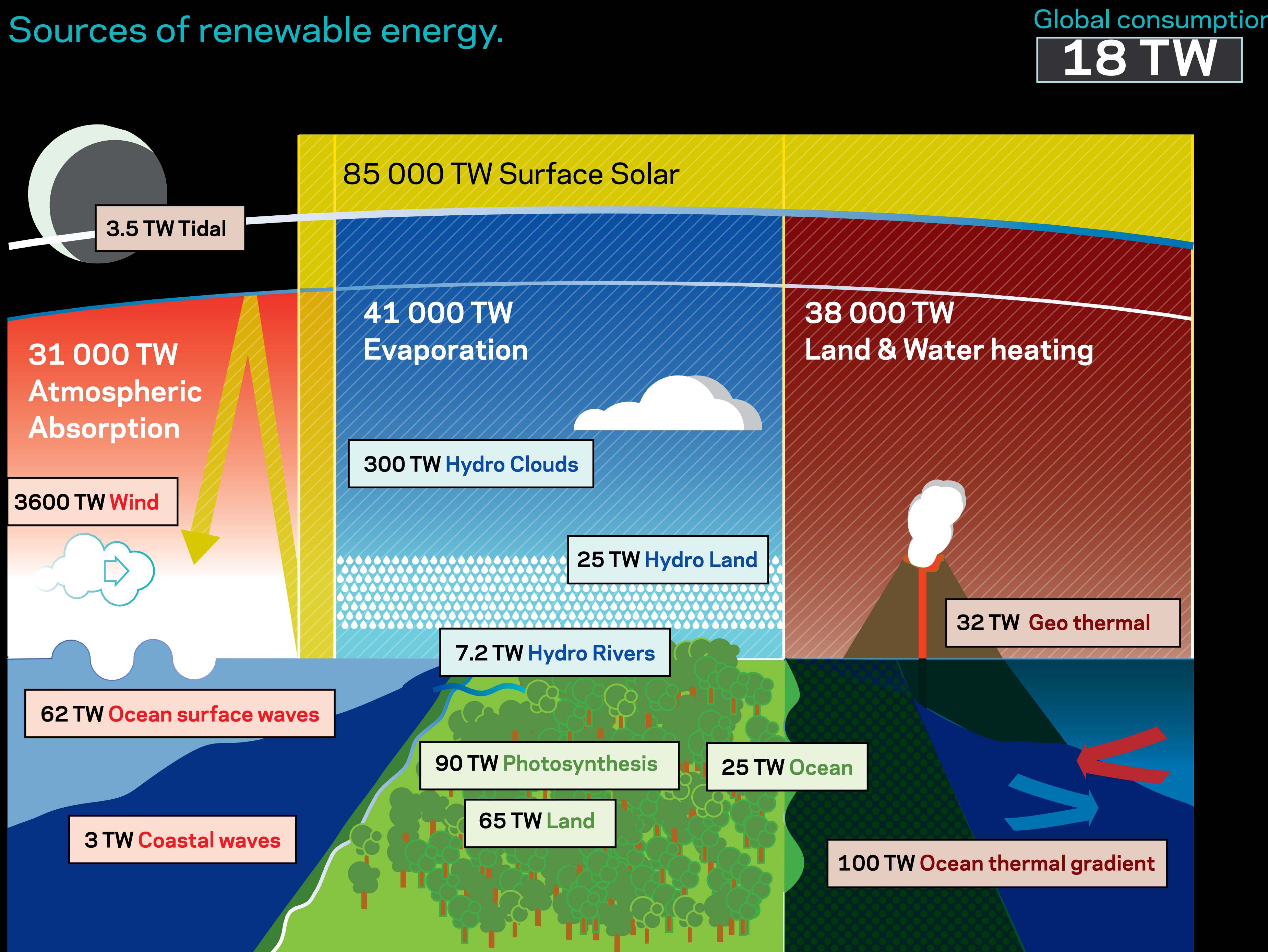
1.5 TW

New Clean Energy:

16-(3+1.5) = > 11.5 TW



GLOBAL POWER CONSUMPTION, TW
15
10
5
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
10 TW
in last
40 years!


Sources of renewable energy.
Global consumption
18 TW
85 000 TW Surface Solar
3.5 TW Tidal
31 000 TW
Atmospheric
Absorption
41 000 TW
Evaporation
38 000 TW
Land & Water heating
300 TW Hydro Clouds
3600 TW Wind
25 TW Hydro Land
32 TW Geo thermal
7.2 TW Hydro Rivers
62 TW Ocean surface waves
90 TW Photosynthesis
25 TW Ocean
65 TW Land
3 TW Coastal waves
100 TW Ocean thermal gradient

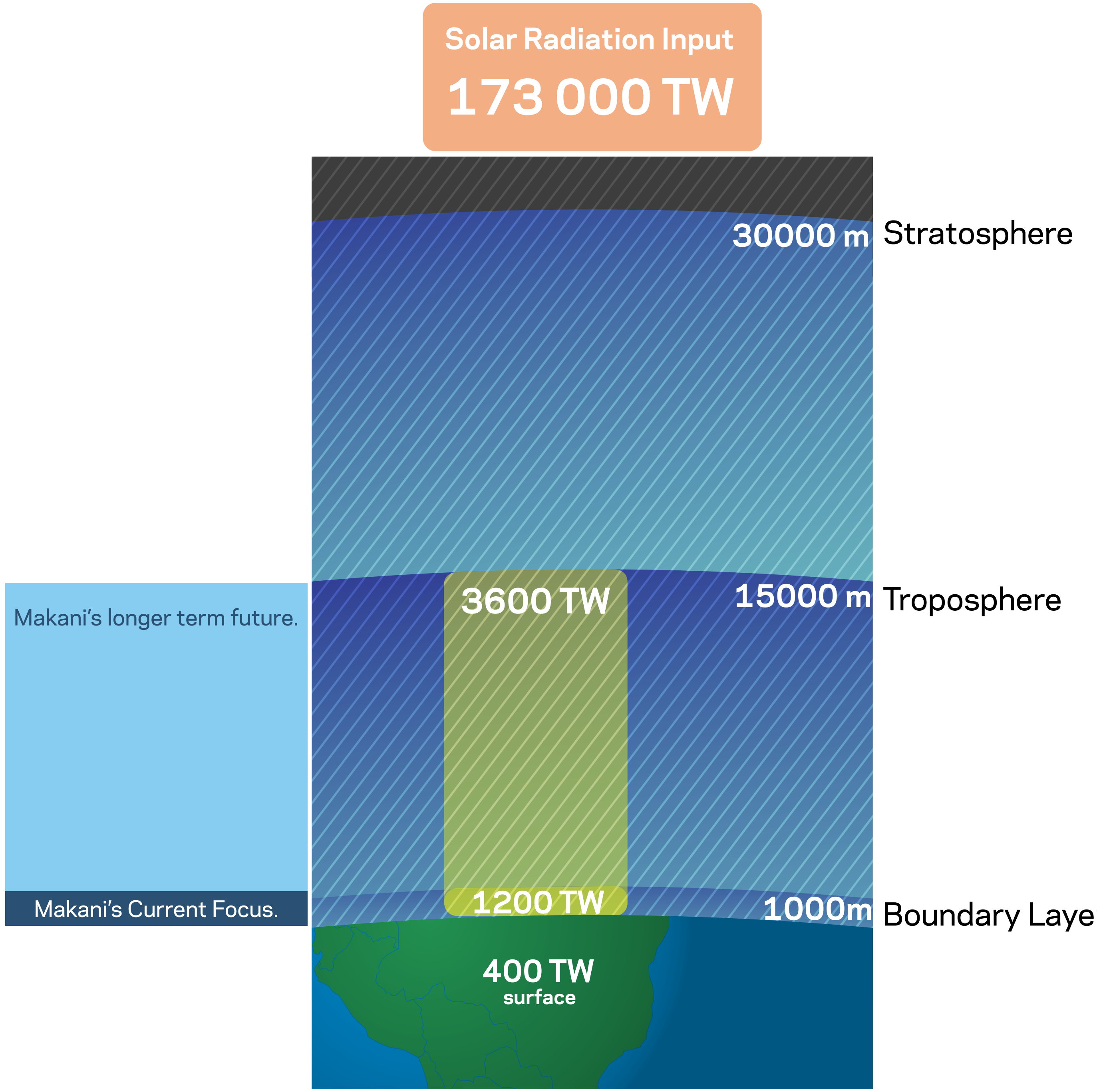
Wind as a resource

Where is the wind?

Wind is a secondary form of solar energy generated by the differential heating and cooling of the atmosphere.

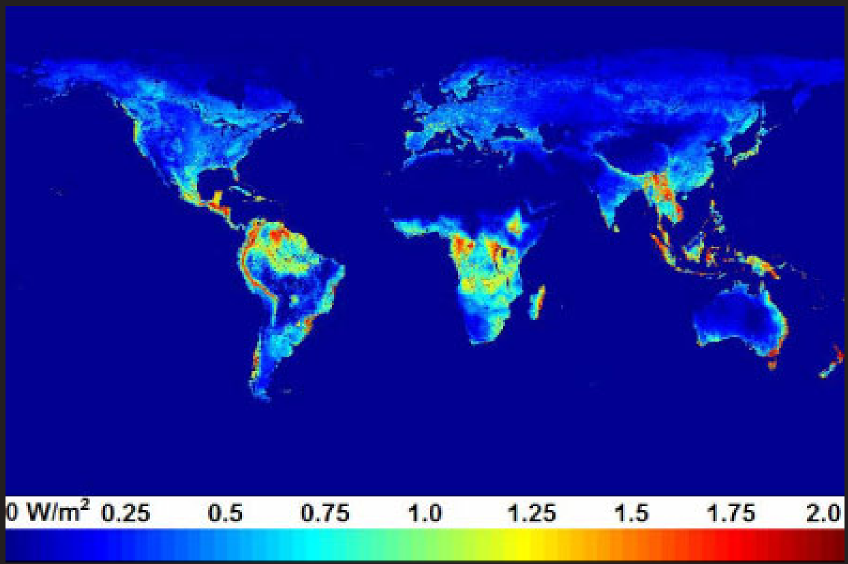
Terrestrially (at 80 meter hub heights) the resource is considered 400 TW globally. Within the boundary layer - liberally defined as 1000 meters, there is a further 800 TW for a resource potential of 1200 TW. In the troposphere up to an altitude of around 15000 meters there is a total resource of around 3600TW.

In the short term Makani is focused on the wind in the boundary layer - ‘mid-altitude’. With tethered wings operating at altitudes between 100 and 1000 meters. (300 - 3000 feet).

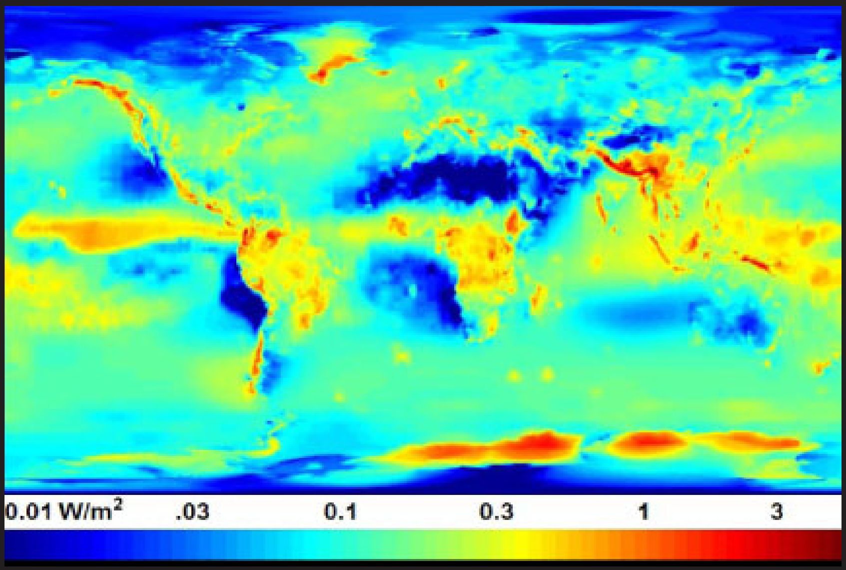


Renewable Power Density Maps

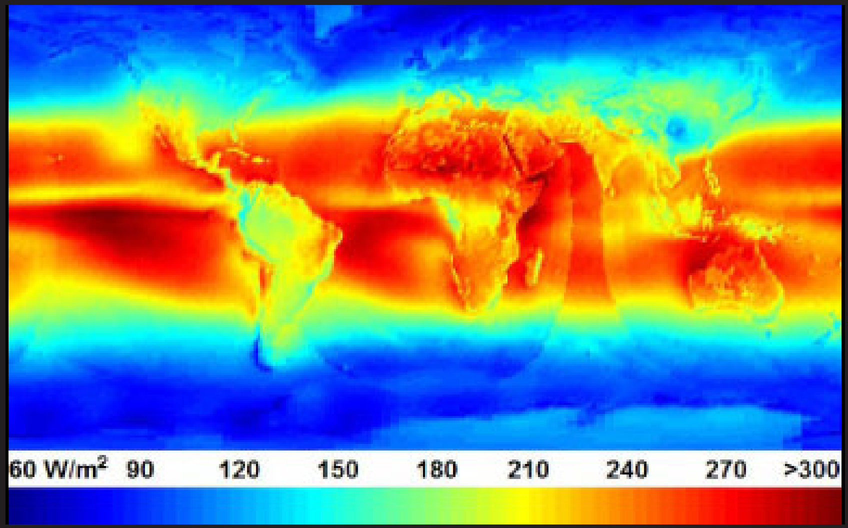
Photosynthesis



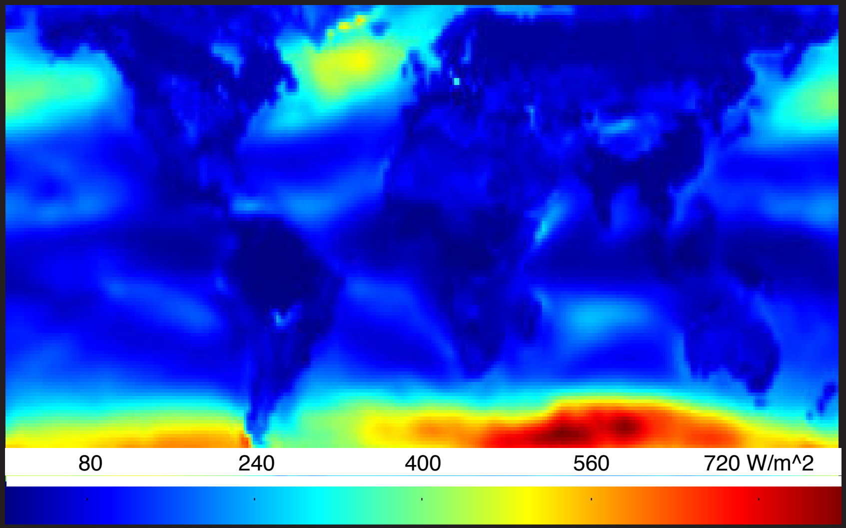
Precipitation (ultimately hydro electic)



Solar Radiation

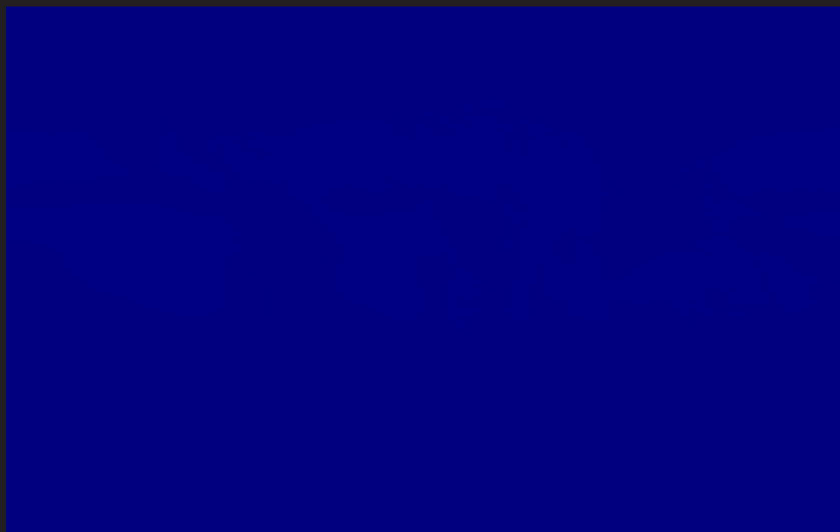


Wind - 50m



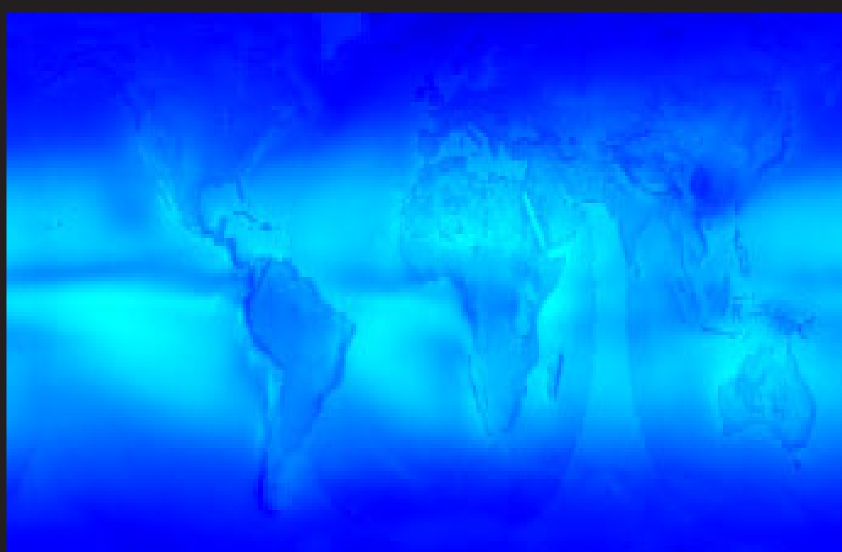
Renewable Power Density Maps (compa red to wind)

Photosynthesis

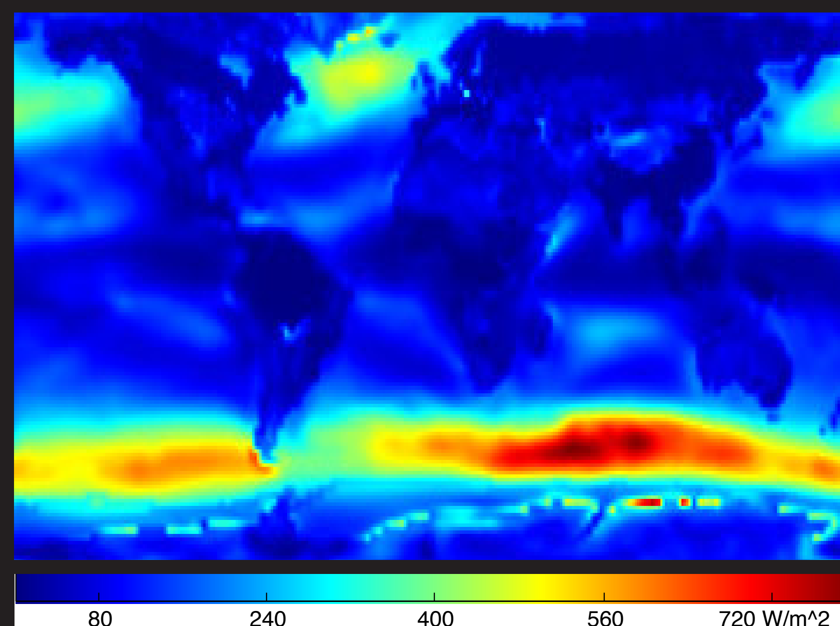


Precipitation (ultimately hydro electic)

Solar Radiation



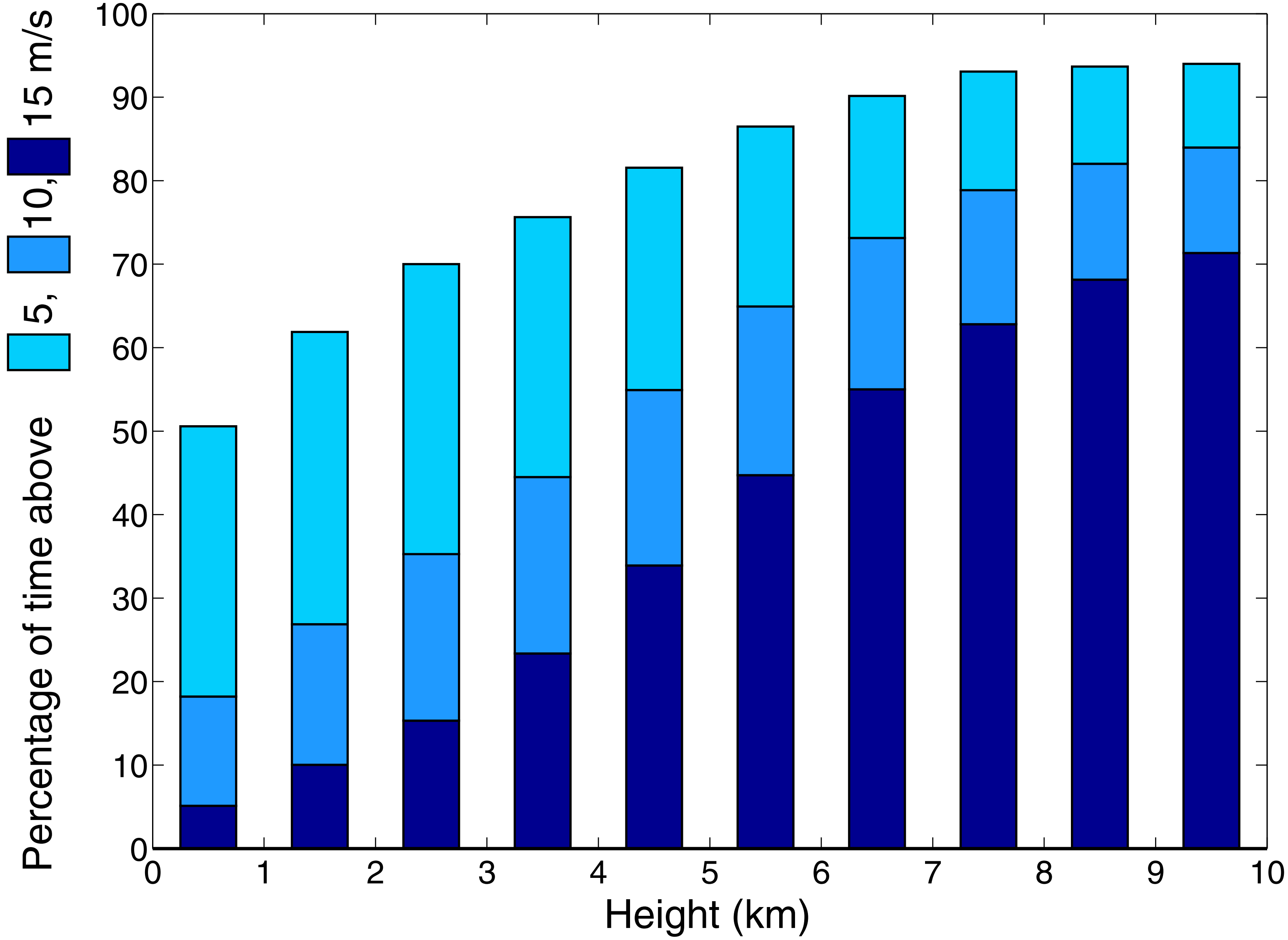
Wind - 50m



Power density (flux) of the "renewables".

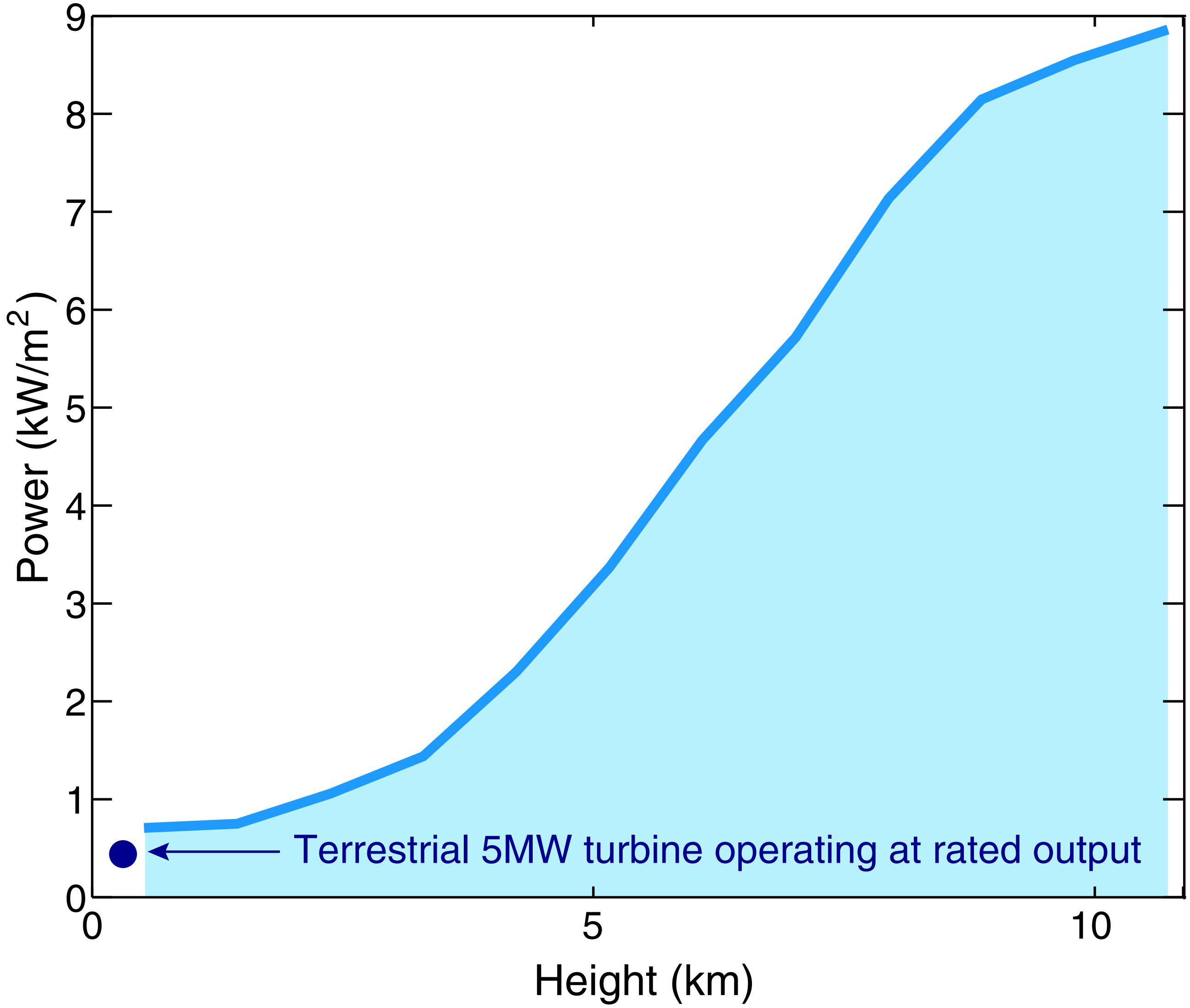
High Altitude wind—Jet Stream	1500 - 500 000	W / m²
Wind	200 - 1000	W / m²
Solar	90 - 300	W / m²
Tidal	0.5 - > 2	W / m²
Ocean Thermal Gradient	0.1 - 0.6	W / m²
Photosynthesis	0.25 - 2	W / m²
Precipitation	0.03 - 3	W / m²
Geothermal	0.05 - 0.25	W / m²

Dependability of high altitude wind as a resource.

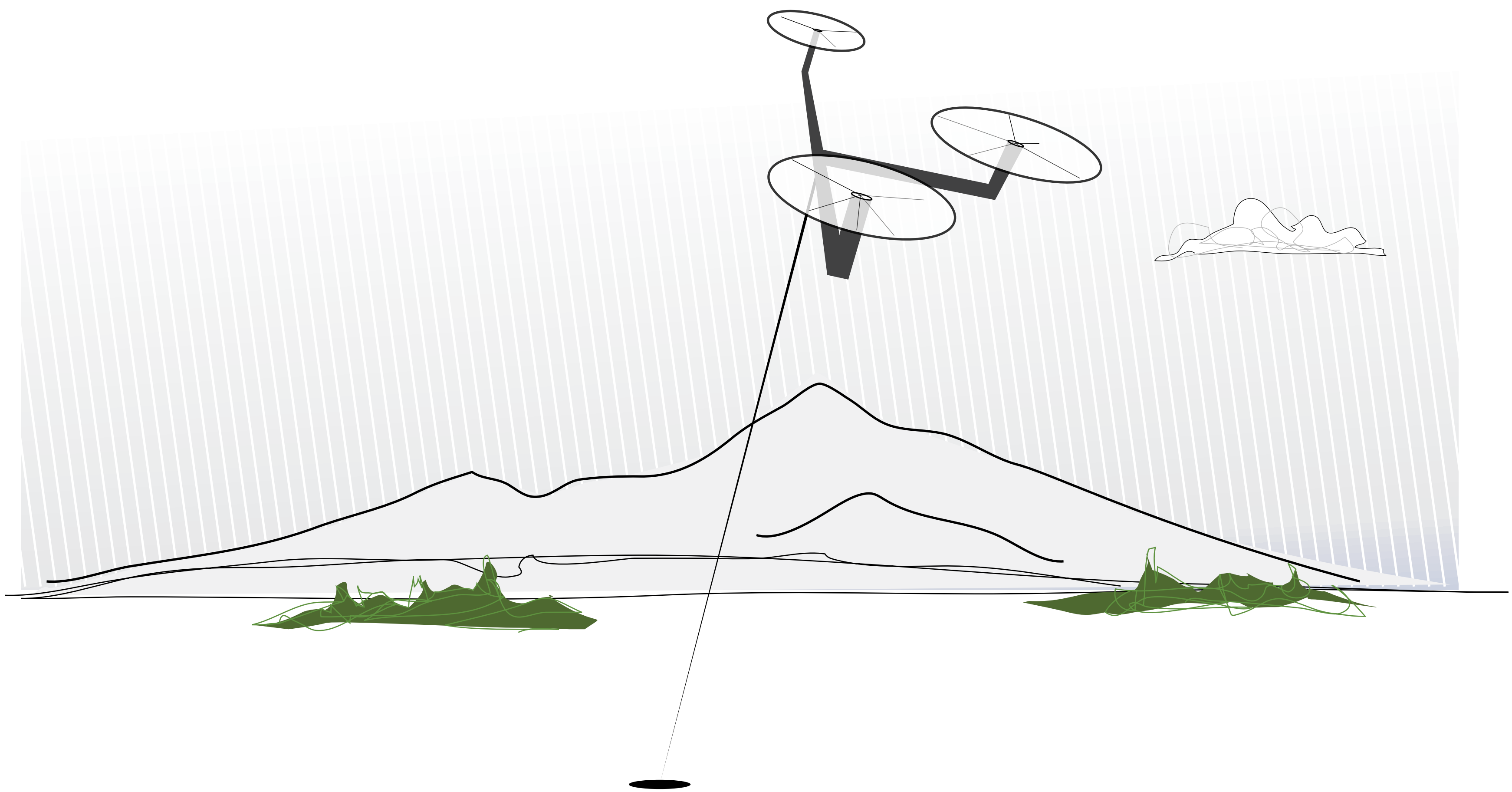


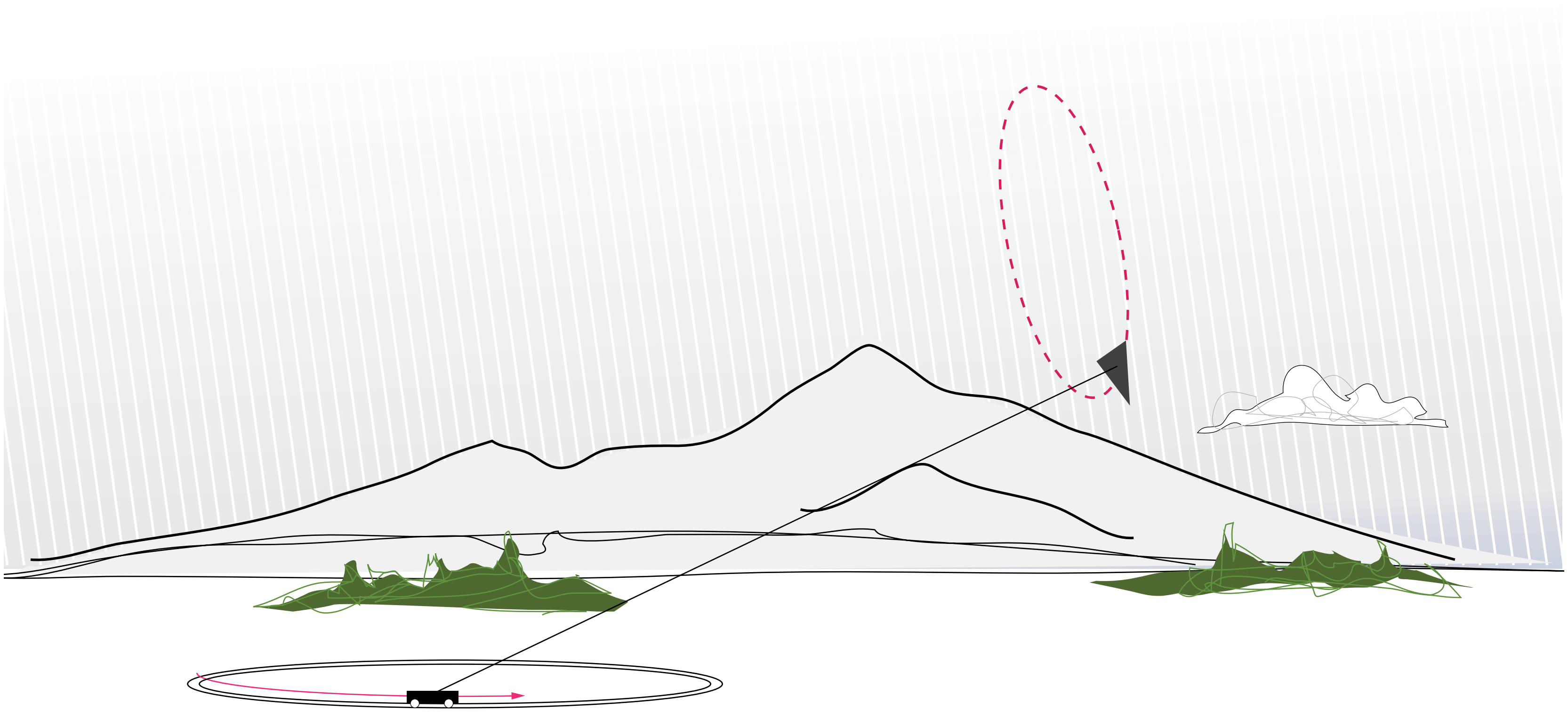
Dependability of high altitude wind as a resource. The fraction of time the wind speed exceeds a given value graphed as a function of altitude (height, in kilometers). Data is taken from the MADIS NOAA Profiler Network - more than 100 Doppler radar stations across the US and Japan. Values shown are averages over all of the stations within the network. This suggests a much higher capacity factor (dependability) for high altitude wind parks than the roughly 30-35% for traditional terrestrial turbines.

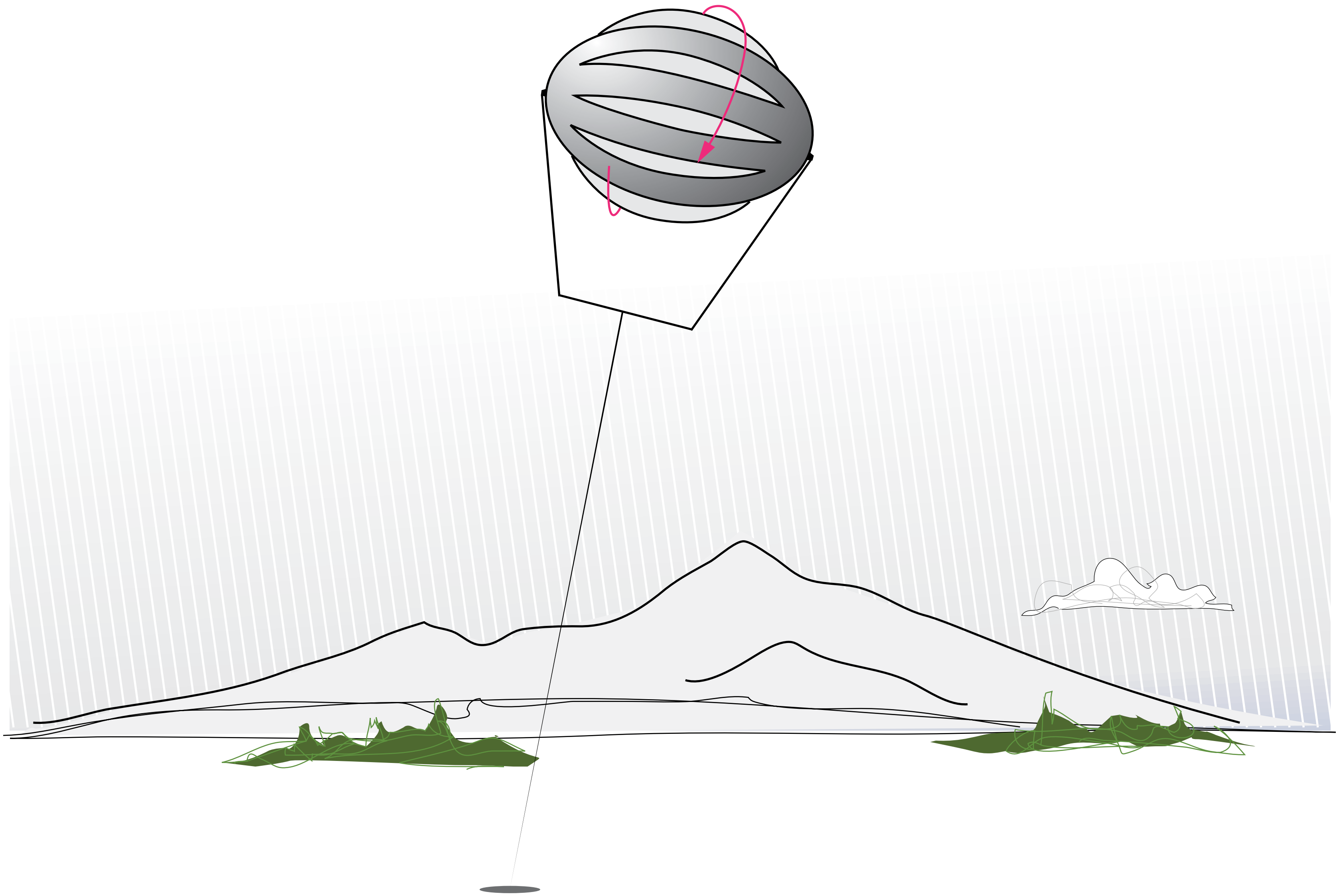
Power contained in high altitude wind.

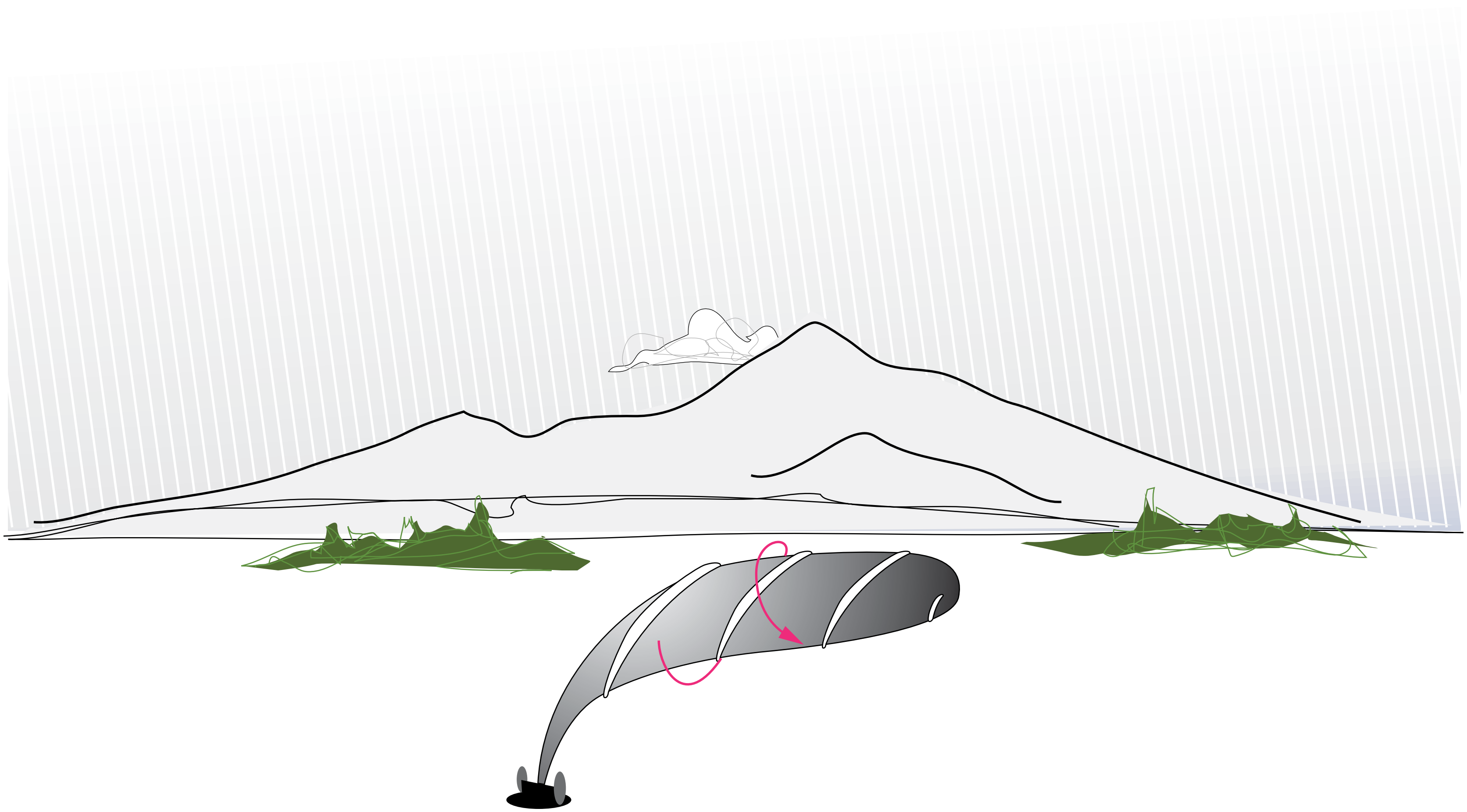


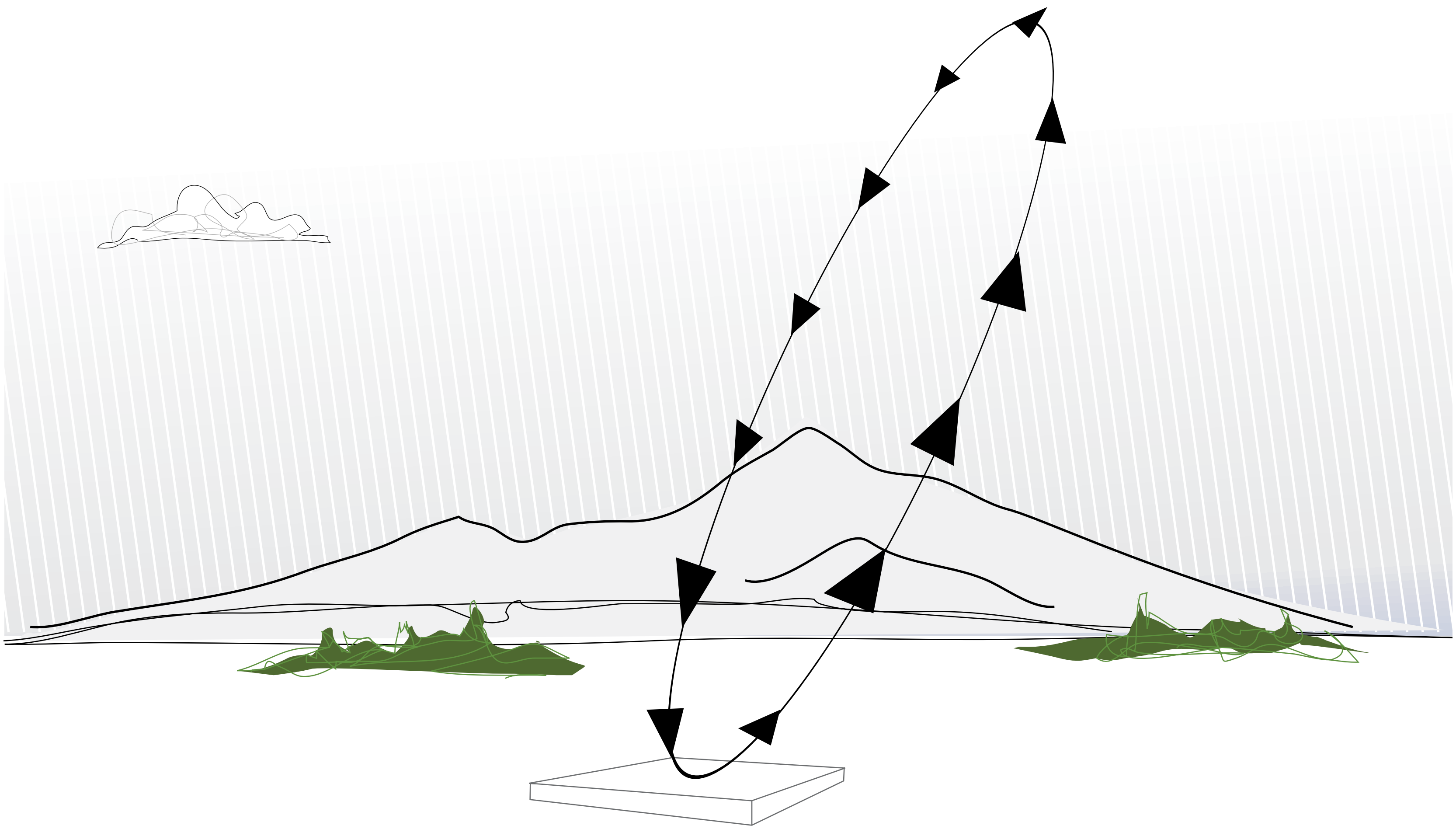
Power contained in High Altitude Wind. This is the kinetic power in kiloWatts per square meter graphed as a function of altitude (height, in kilometers). Data is taken from the MADIS NOAA Profiler Network - more than 100 Doppler radar stations across the US and Japan. Values shown are averages over all of the stations within the network. For comparison the kinetic power per square meter of a large terrestrial turbine operating at rated capacity is shown in green.



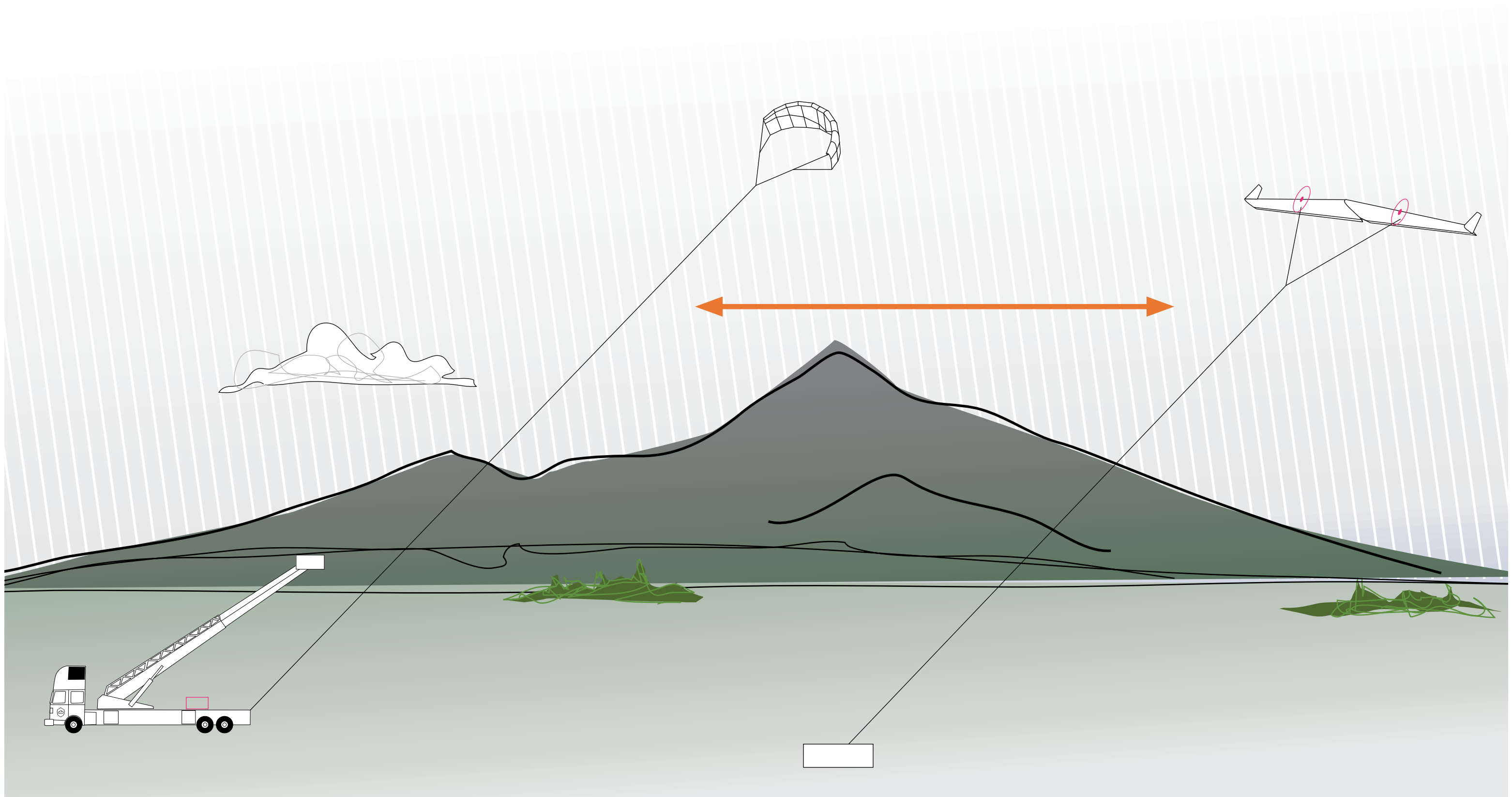




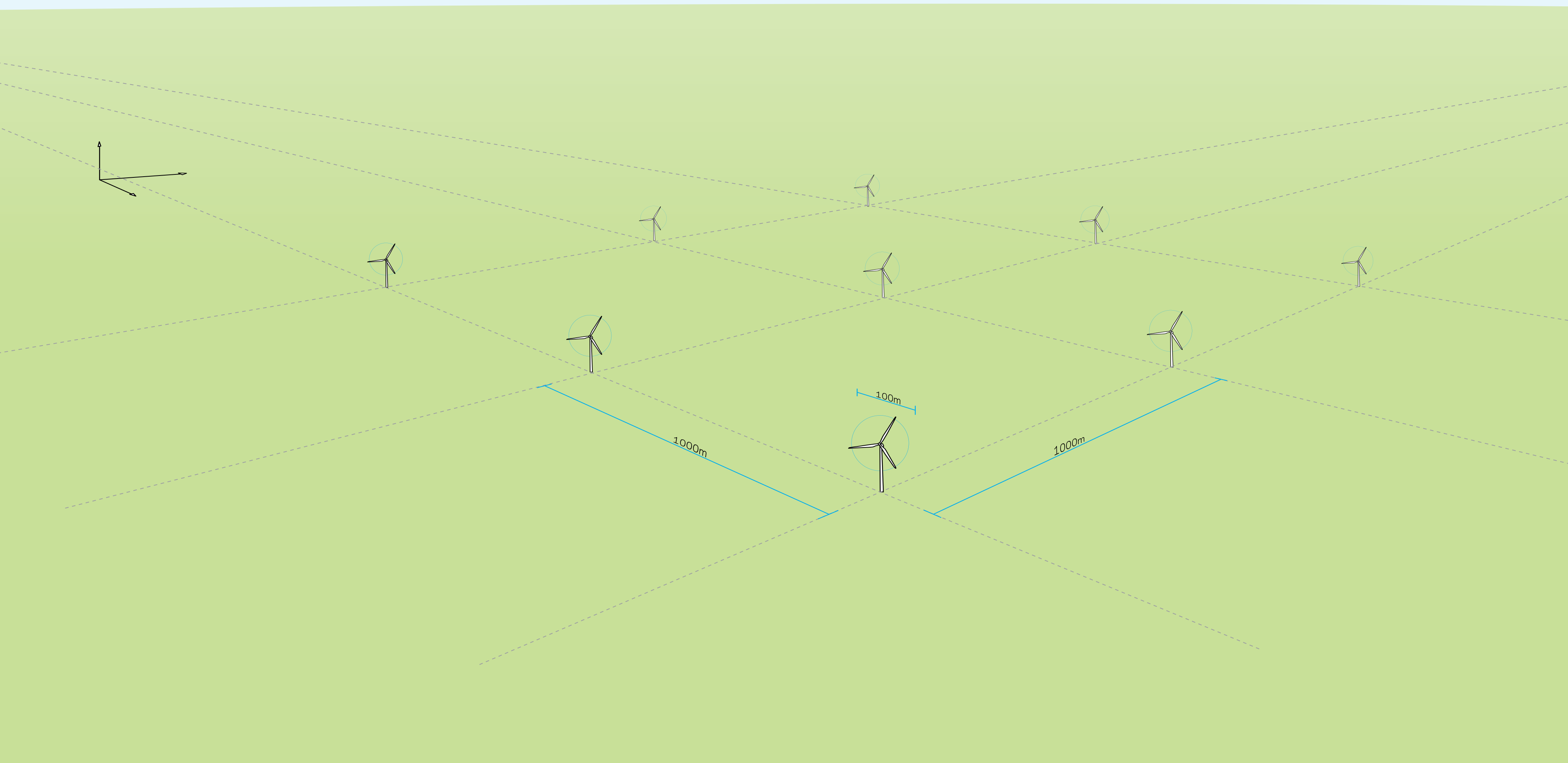




Two remaining candidate architectures.

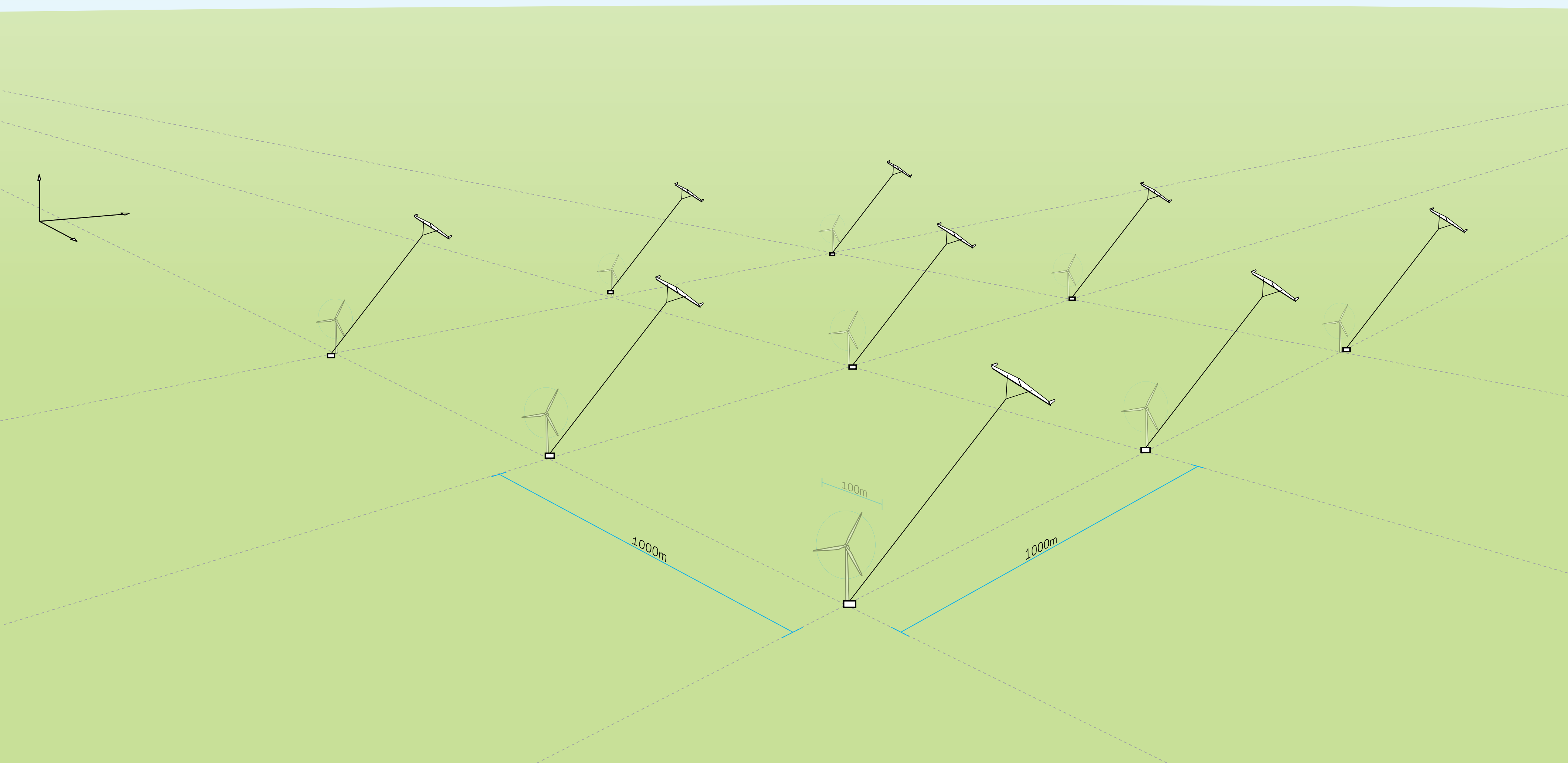


Traditional wind FARM - 1-2 W/m² (Land Area)



Makani KITE FARM

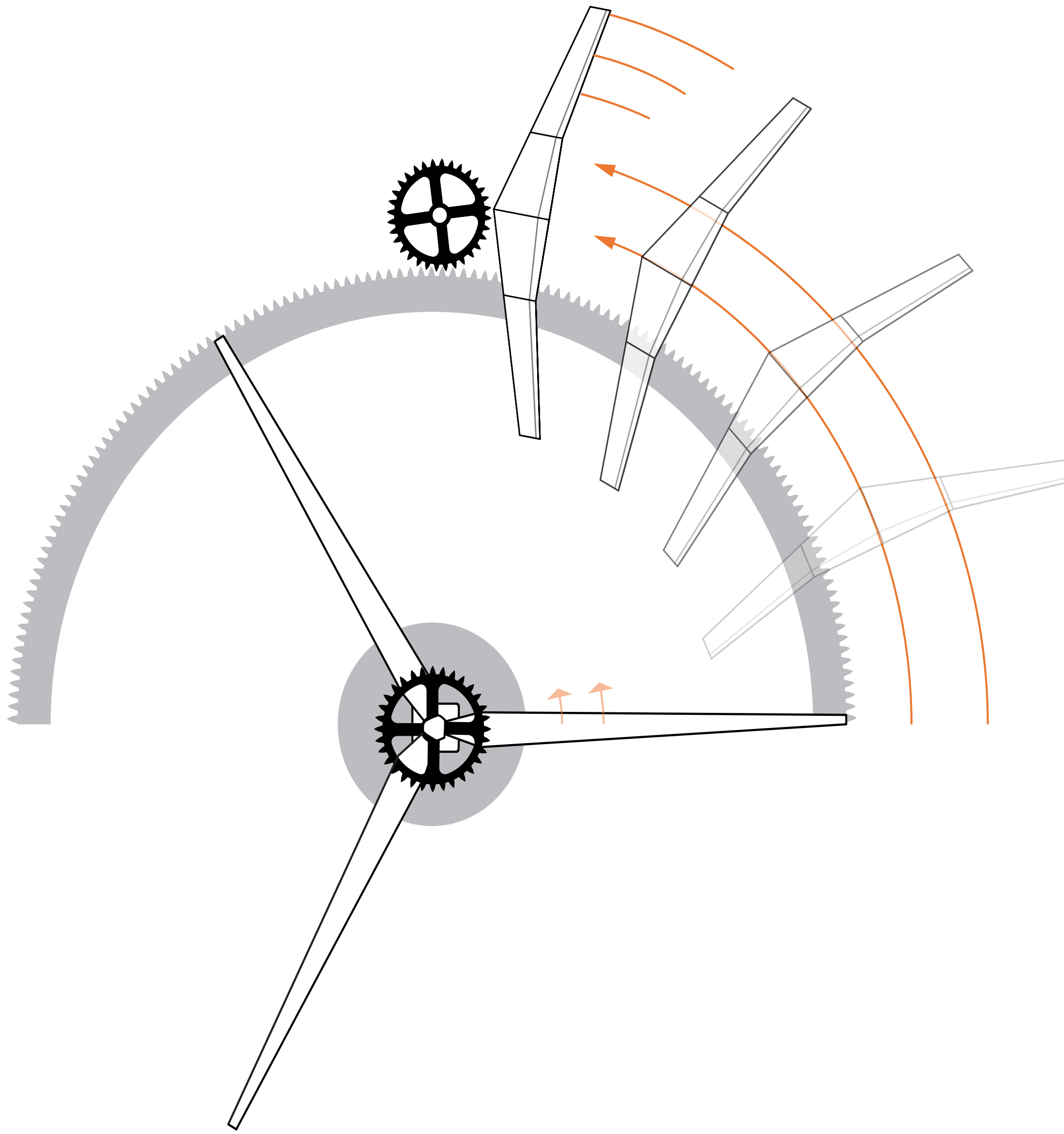
Similar layout and spatial density to existing wind farms, higher capacity factor and power capacity per unit of land area.



Aerodynamic gear (More with Less)

One way of describing the principal advantage of Makani technology is that we have built a continuously variable aerodynamic gear that sweeps through the maximum area of power producing sky with the minimum amount of material (wing).

The high speed wing allows us to remove completely gearboxes and low speed direct drive generators and replace them with high speed electric generators that are small, lightweight, and ultimately much lower cost.



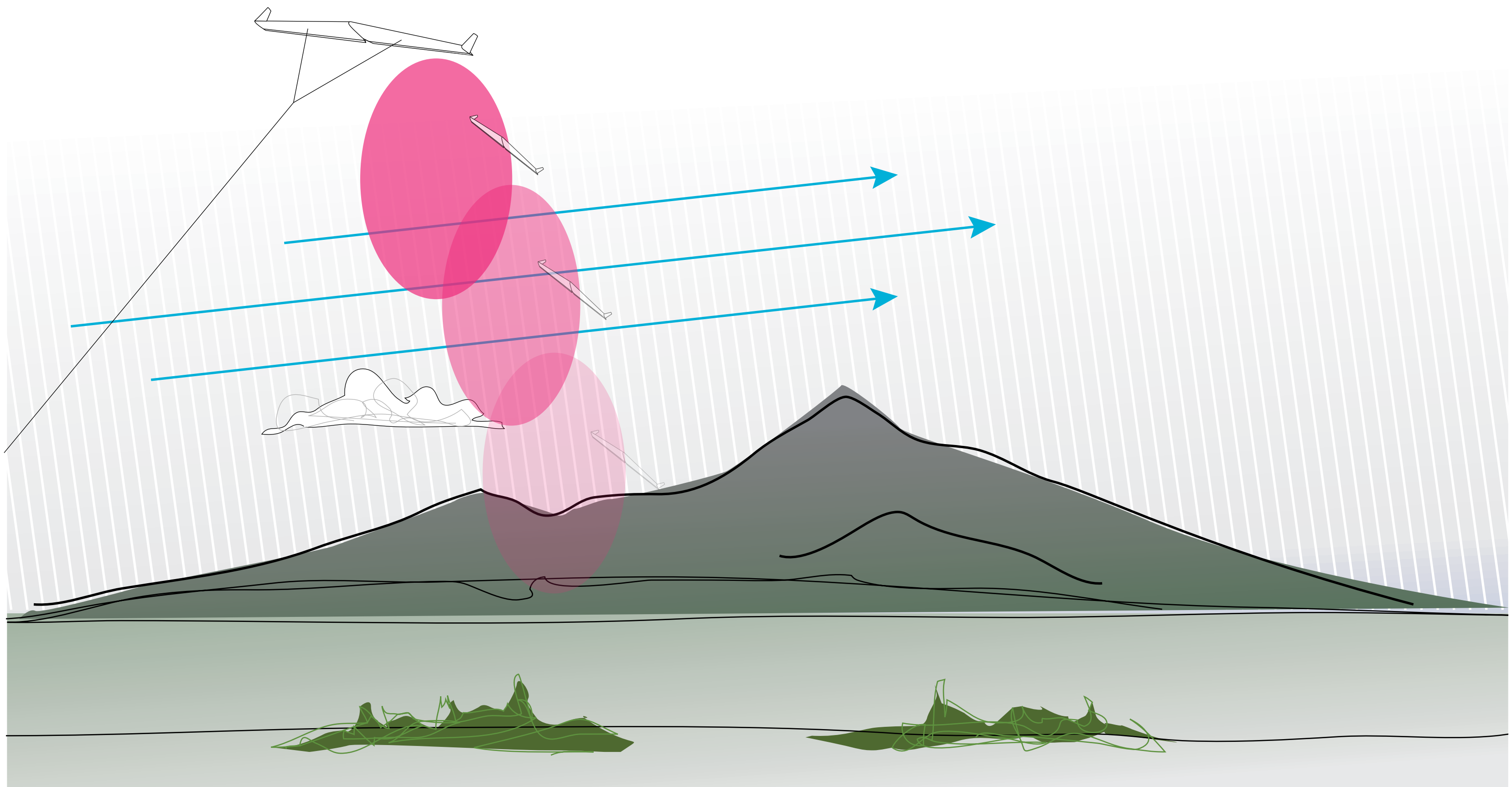
Greater operational range

One major advantage of Makani Power technology is the greater dynamic range of this method of extracting wind energy. The wing because it is not fastened to a tower, can be flown at an altitude and along a flight path that is most efficient for the given wind conditions and wing design.

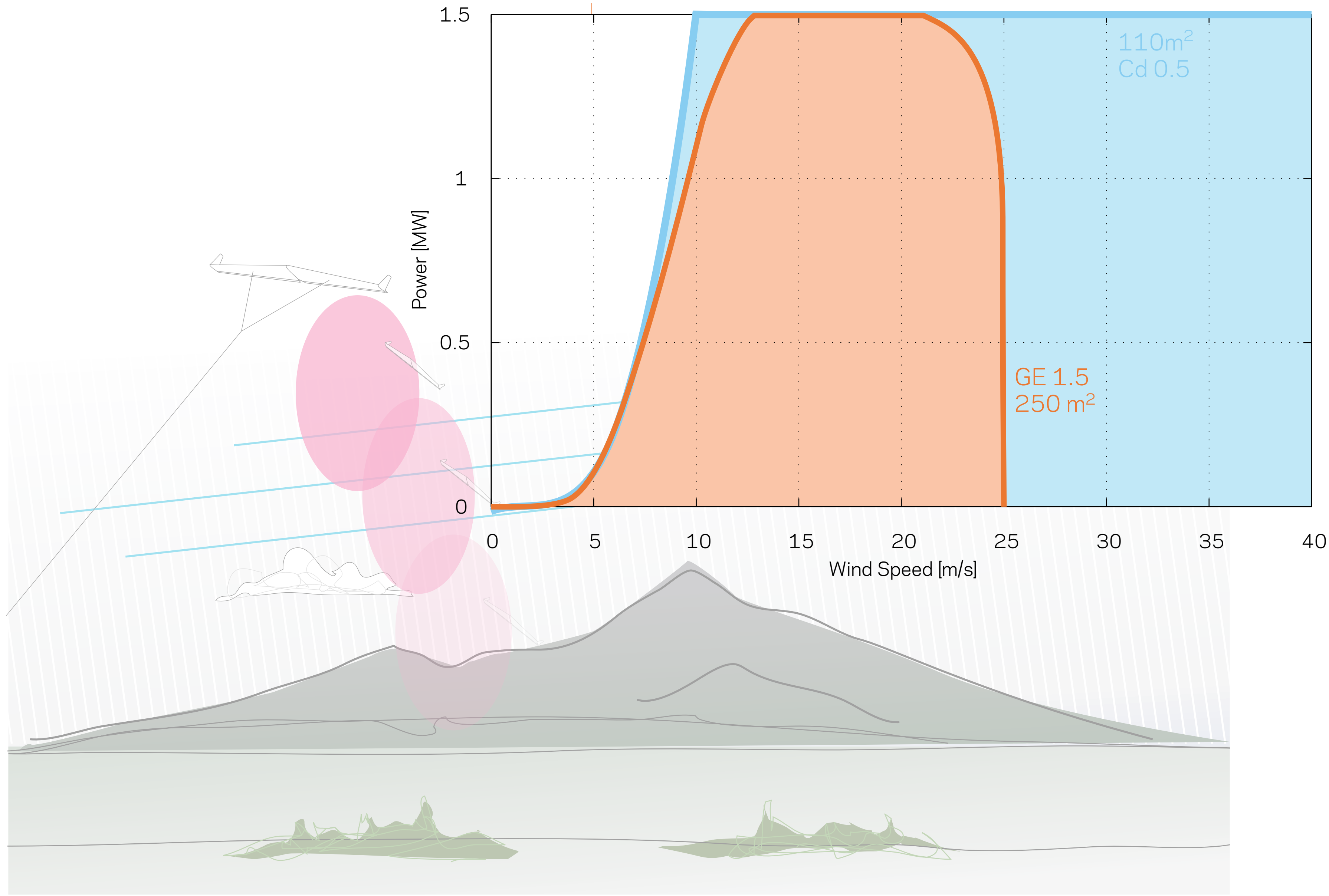
As wind speed increases kite can fly higher.

As wind speed decreases kite can fly lower.

This allows the machine to get maximum performance and power generated as a function of the material (and therefore cost) of that machine.

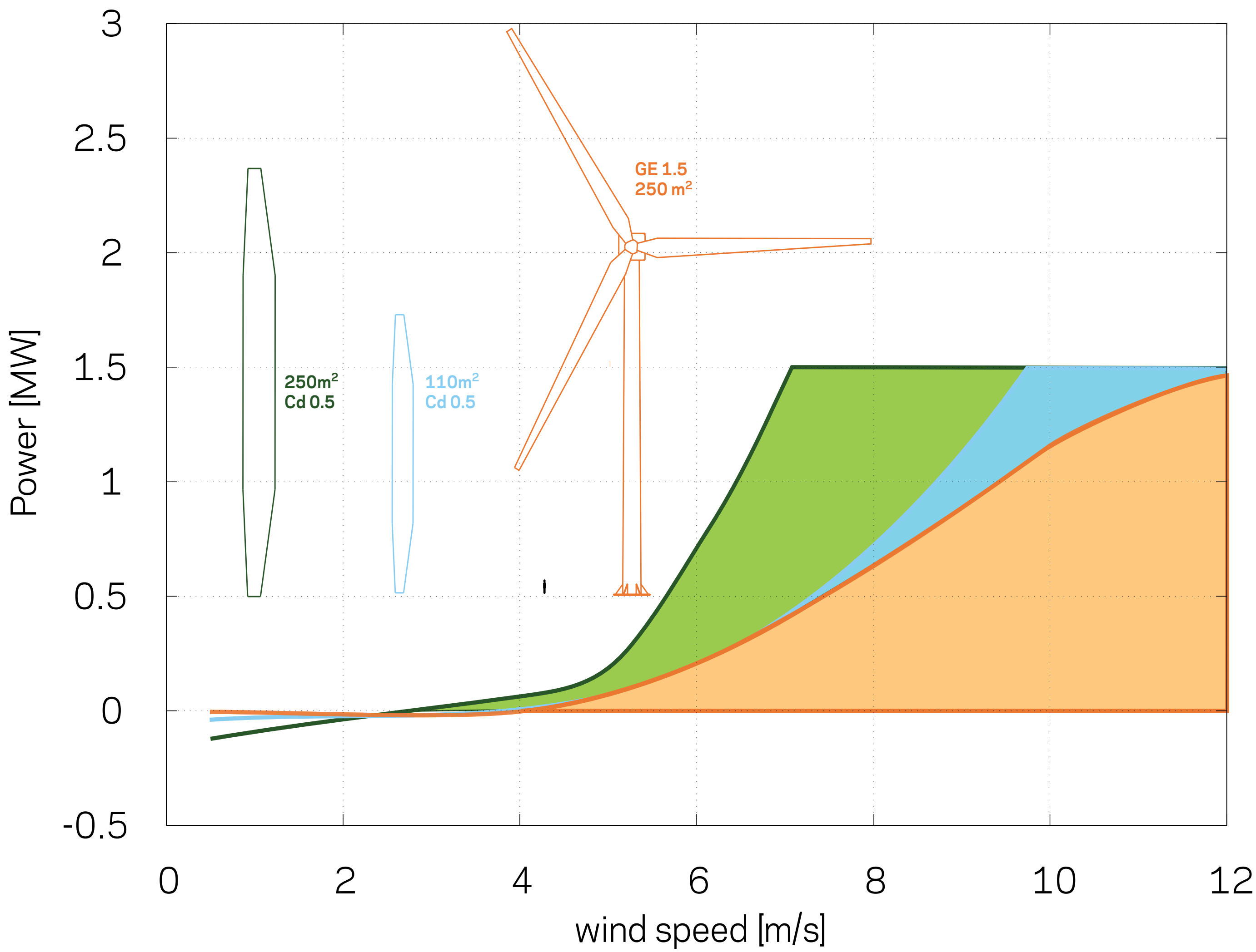


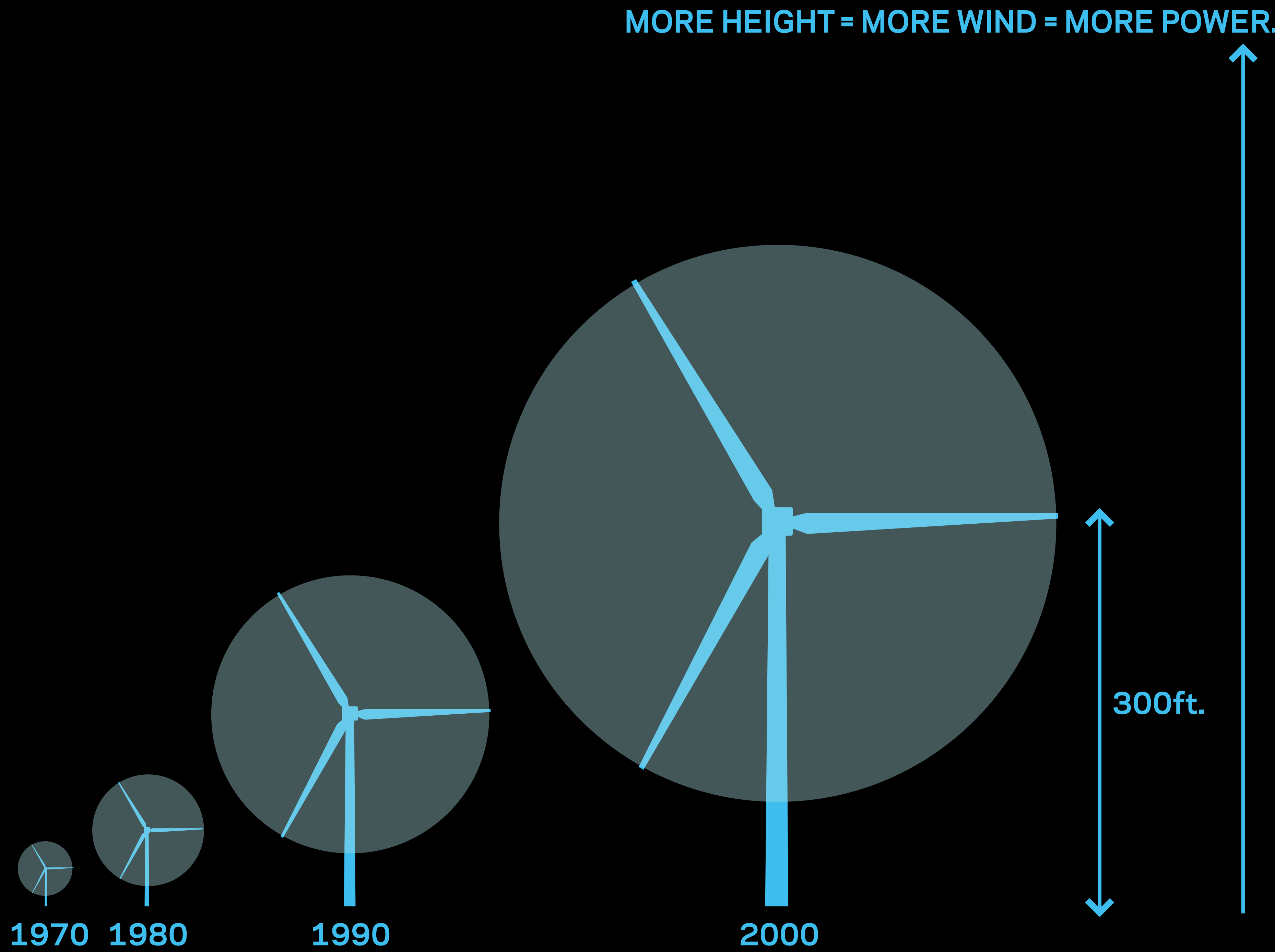
Greater Operational Range

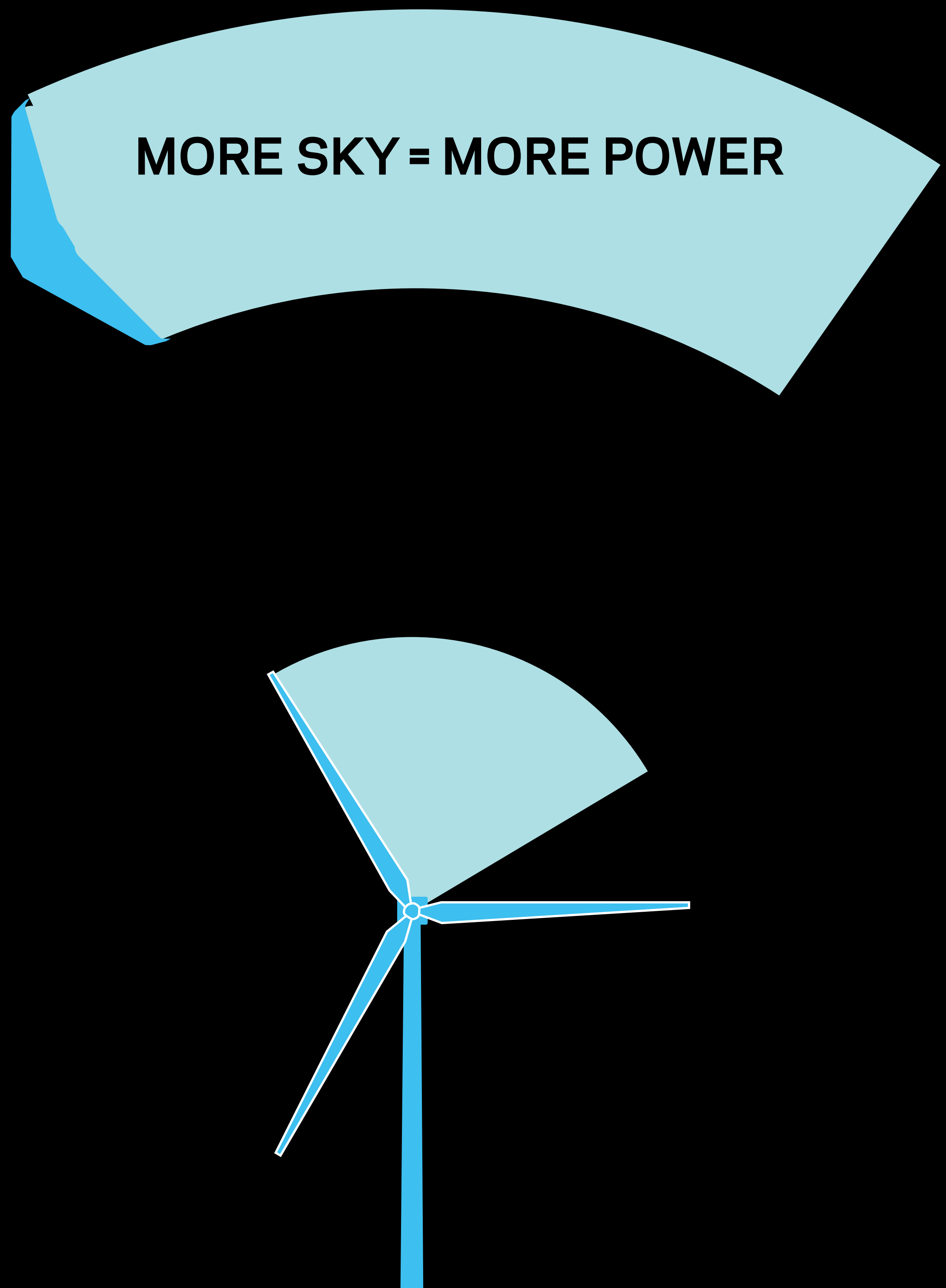


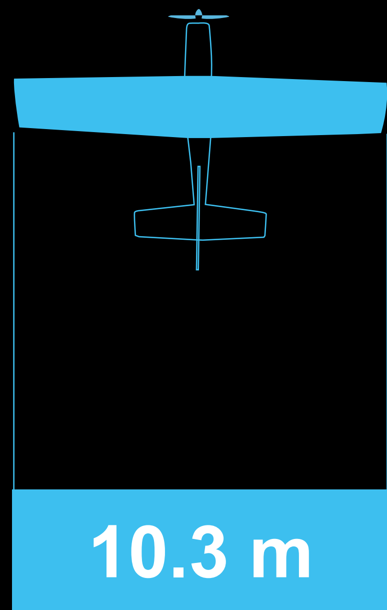
Power curves: Advantages over traditional wind

Perhaps one of the greatest advantages makani will have is at low wind speeds where we can reach full rated power much earlier. This will enable previously uneconomic wind sites (classes 2-4) to potentially become economic wind projects.



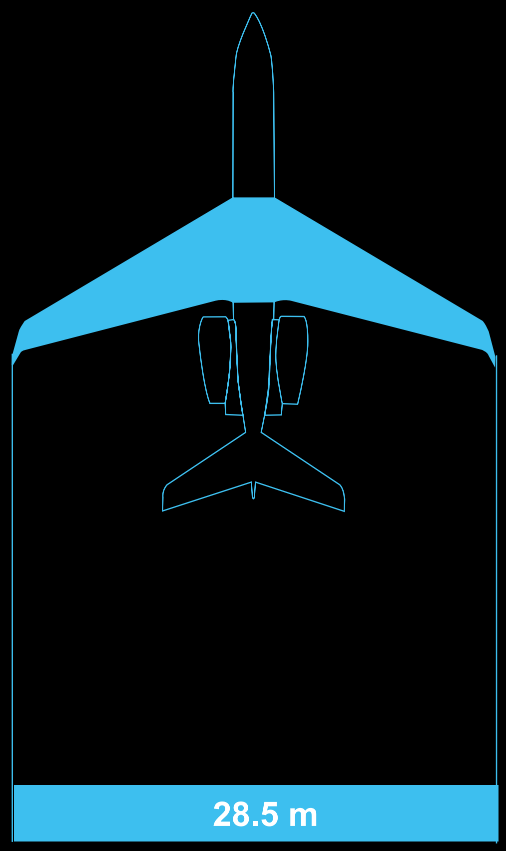

MORE HEIGHT = MORE WIND = MORE POWER.
300ft.
1970
1980
1990
2000


MORE SKY = MORE POWER

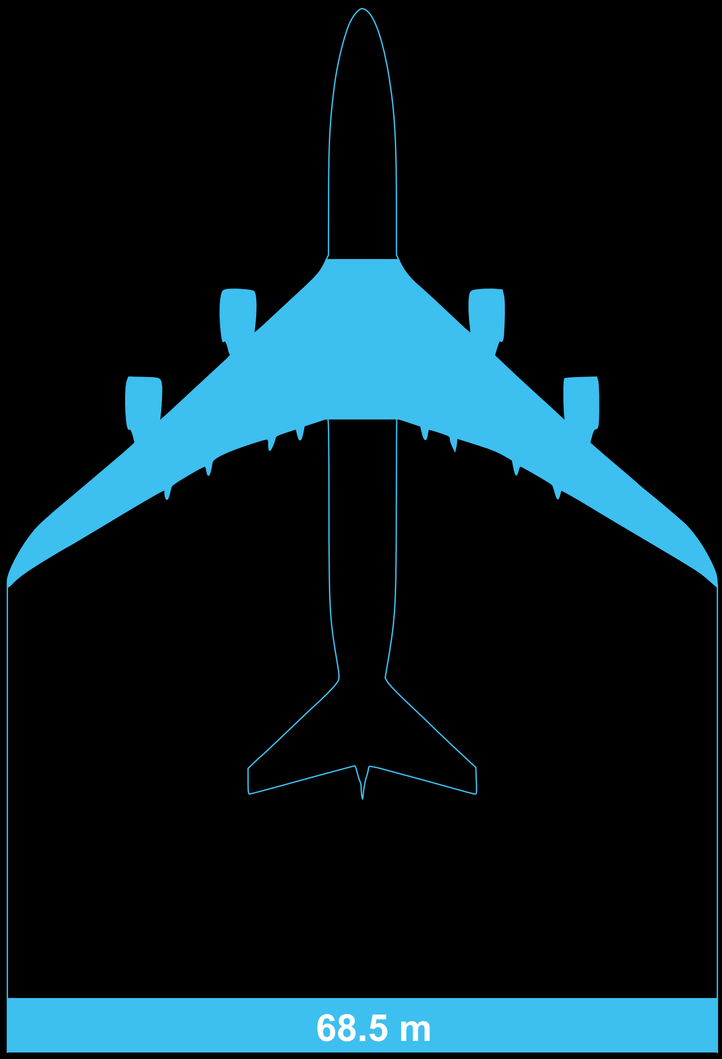


CESSNA

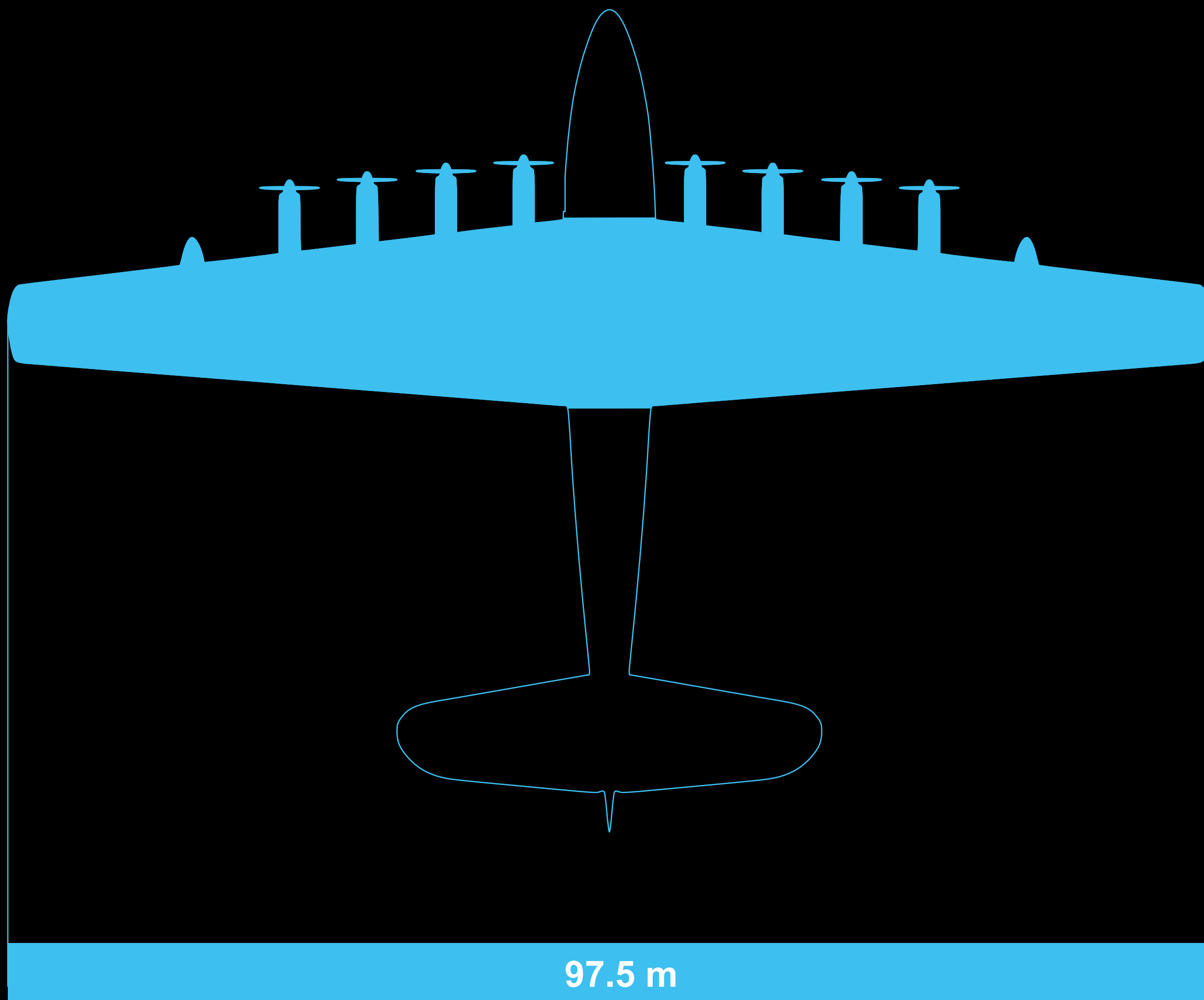
230 kW



GULFSTREAM
1.3 MW



BOEING 747
6 MW



SPRUCE GOOSE

15 MW


M.P.
SG1974
DRAGOTTA

Next steps:

Full scale prototypes
Pilot plant testing
Proof of insurability and reliability

$$$$$$$$

Following steps:

Production facilities
Deployment

$$$$$$$$$

Demand : Consumption & Efficiency

Why watts ?

Allows you to compare activities on different timescales.

Allows you to consider non-carbon effects of using so much power.

If you do something yearly (like fly 105,000 miles), it contributes:

$$\frac{168{,}207 \text{ kilometers}}{1 \text{ year}} \times \frac{1 \text{ year}}{31{,}536{,}000 \text{ seconds}} \times \frac{1.40 \text{ megajoules}}{1 \text{ kilometer}} = 7{,}462 \ \frac{\text{Joules}}{\text{second}} = 7{,}462 \text{ Watts}$$

If you do something monthly (like your electricity bill), it contributes:

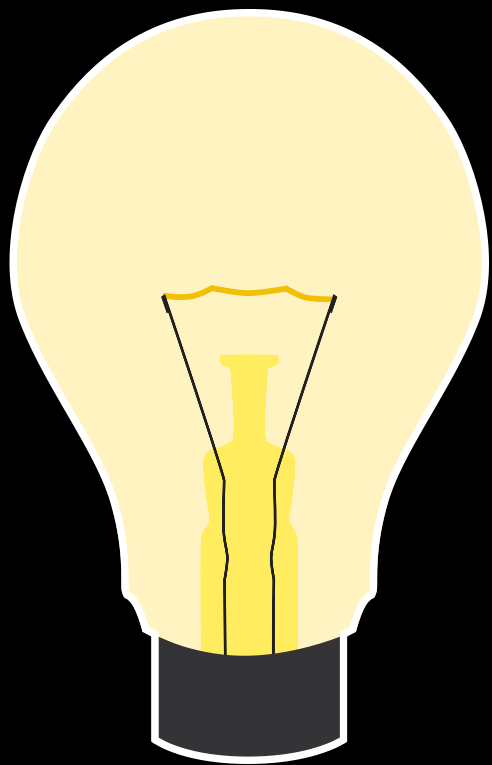
$$\frac{122 \text{ kilowatt} \cdot \text{hours}}{1 \text{ month}} \times \frac{1 \text{ month}}{2{,}952{,}000 \text{ seconds}} \times \frac{3.6 \text{ megajoules}}{1 \text{ kilowatt} \cdot \text{hour}} = 170 \ \frac{\text{Joules}}{\text{second}} = 170 \text{ Watts}$$

If you do something daily (like drink 1 Energy drink), it contributes:

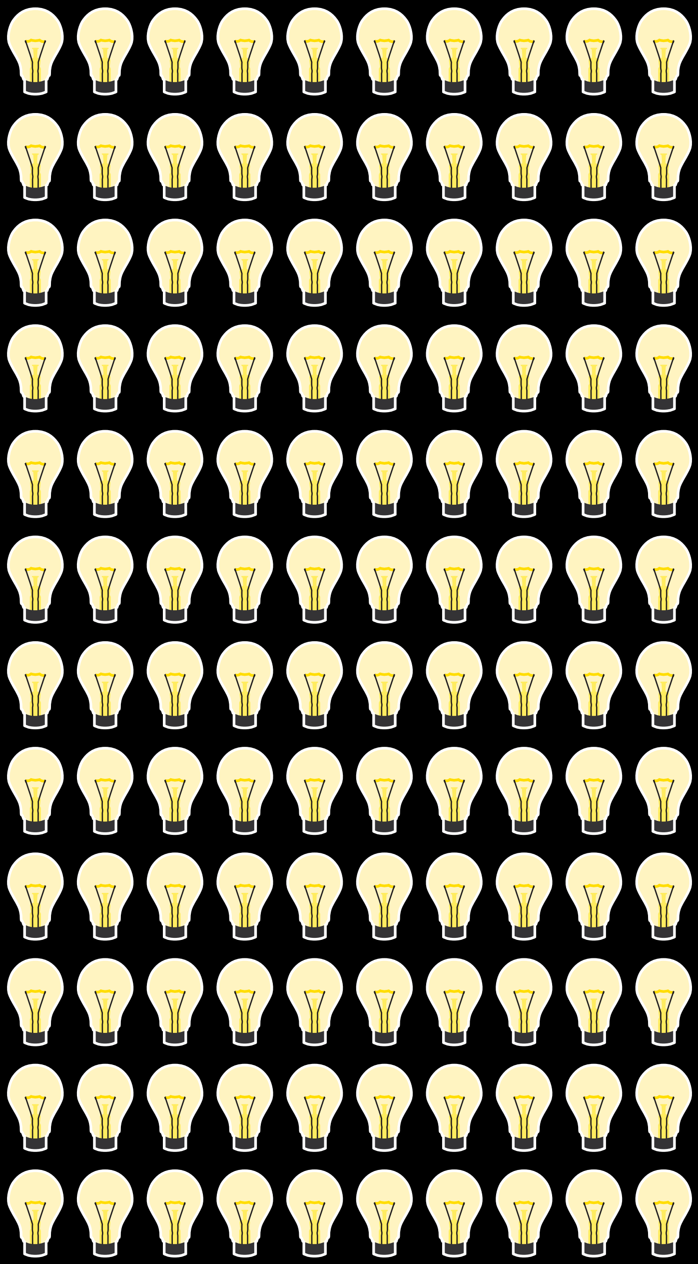
$$\frac{1 \text{ energy drink}}{1 \text{ day}} \times \frac{1 \text{ day}}{86{,}400 \text{ seconds}} \times \frac{7.84 \text{ megajoules}}{1 \text{ bottle}} = 90 \ \frac{\text{Joules}}{\text{second}} = 90 \text{ Watts}$$

Yearly things + Monthly things + Daily things = your lifestyle in watts.

"Watts per always" - your life in light bulbs.



A 12,000 Watt lifestyle is 120 x 100 watt light bulbs burning permanently. (Or 920 Compact Fluorescents)



LATEST 11/15/08 The problem of understanding and changing the way we produce and use energy is unsolved. It is confusing. Climate change is the result of the way

WattzOn alpha Personalizing energy consumption.

USER NAME | PASSWORD | LOGIN

START TRACKING YOUR LIFE, ITS FREE! SIGN UP »

YOUR DATA | FORUMS | EED | BLOG | ABOUT | CONTACT

Climate change is a global problem. But it's individuals who will create the solution.

Wattzon gives you the tools you need to track your energy consumption, compare it to others, understand its consequences and discover the steps you need to take to help solve climate change. Ready to get started?

CREATE YOUR CHART »

1 2 3 4 5

AVERAGE USER'S ENERGY USAGE

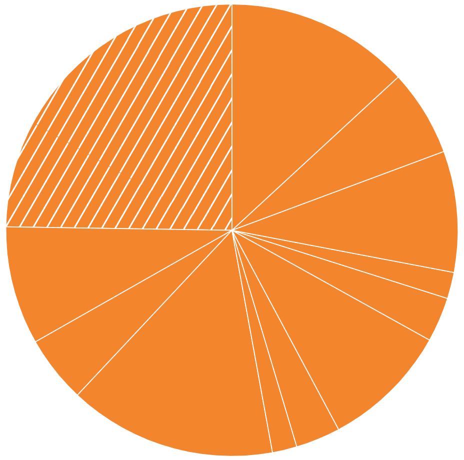
6,357W

CURRENT USER'S 1,207,098

NEWST USERS ENERGY BREAKDOWN

Kirk22 »

10,936W



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POP! TECH

What is WattzOn?

WattzOn is a free online tool to quantify, track, compare and understand the total amount of energy needed to support all of the facets of your lifestyle ... *CONTIUE READING »*

WHY WATTS

A watt is a unit of power that indicates the rate at which you are using energy. For WattzOn, we normalize all of your profile answers ... *CONTIUE READING »*

60Hz buzz

We've been very fortunate to receive such praise from our users and the press...
CONTINUE READING »

FROM THE BLOG

I'M TOM, A RECOVERING CONSUMER

My name is Tom and I have been a recovering consumer for five years. Since I'm new here, I'd like to let you know a little bit about...

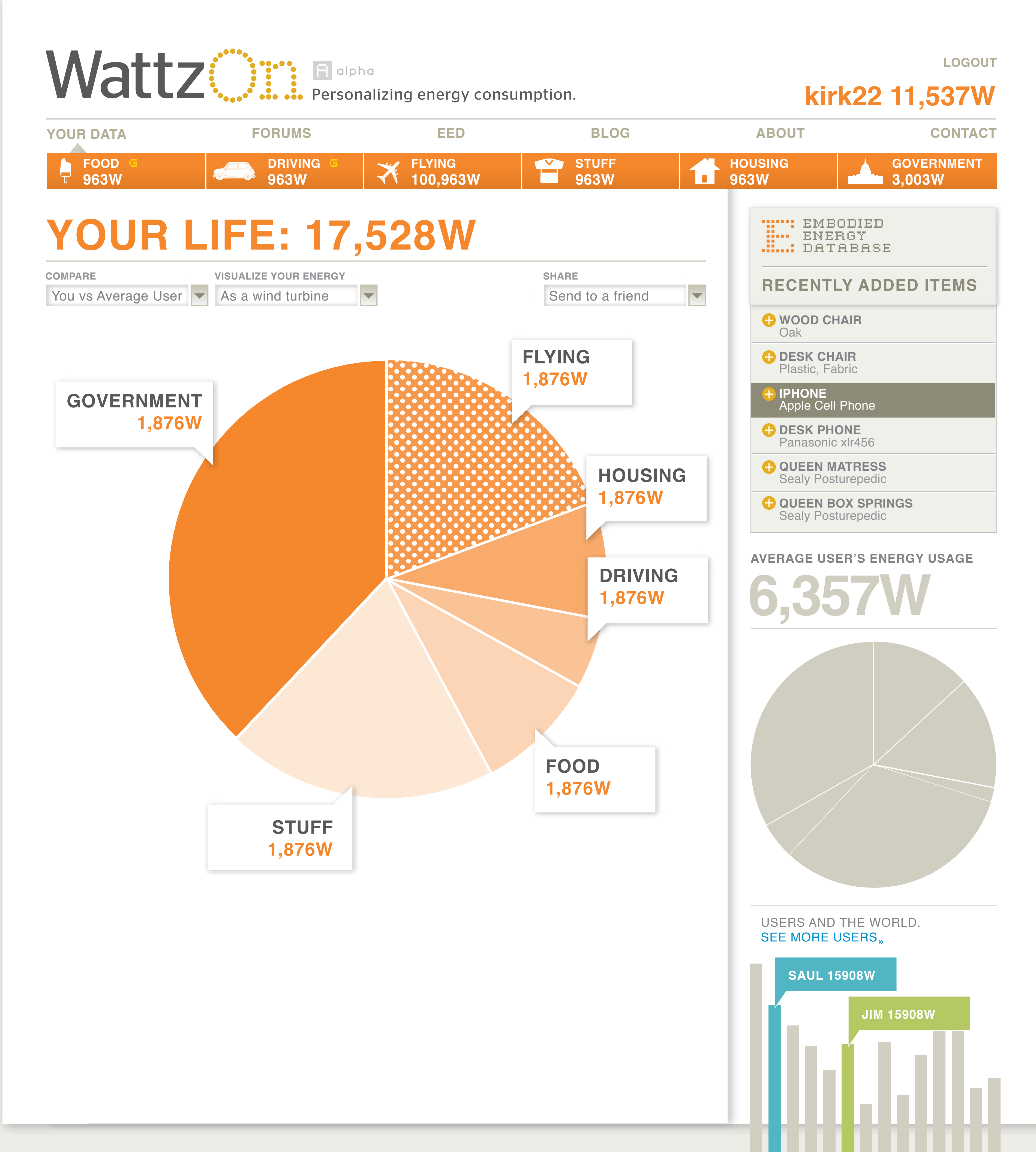
CLIMATE CHANGE, RECALCULATED

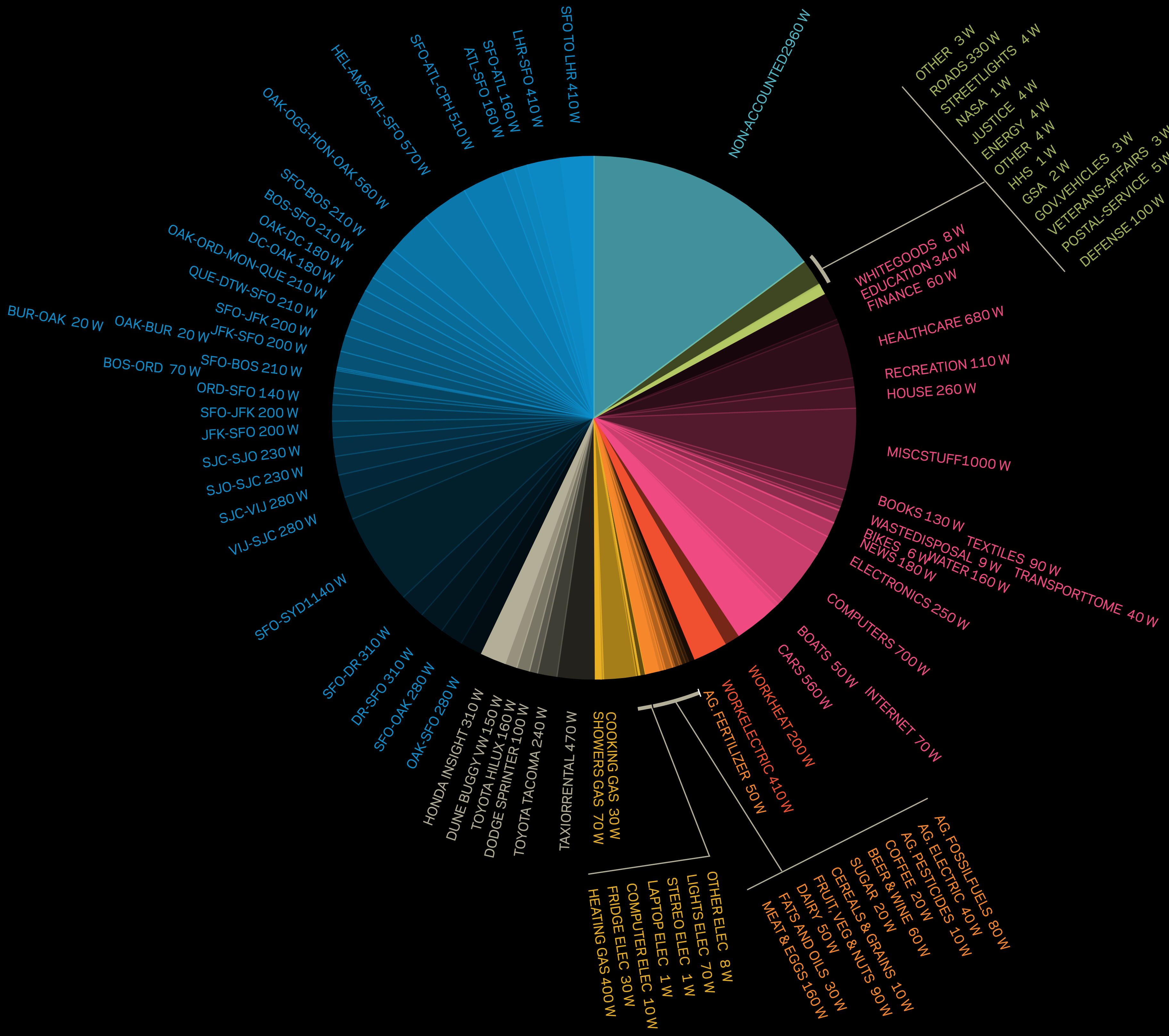
On January 16, 2009, I gave a talk at the Long Now Foundation — hosted by Stewart Brand, this was a long discussion that placed our personal...

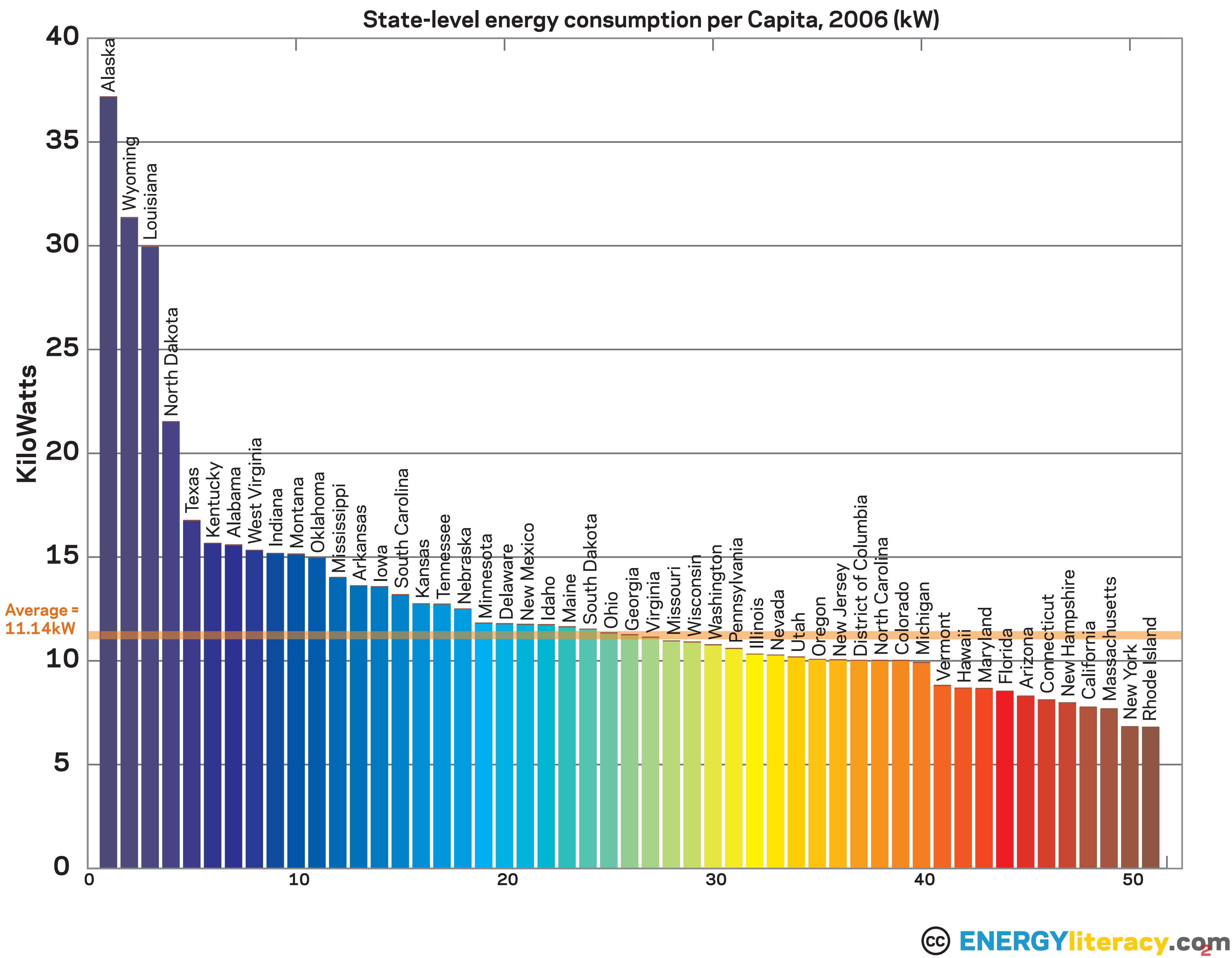
NEW YEAR'S RESOLUTION: LOSE ENERGY

January is in full swing and millions of people are piling into gyms and counting calories to meet their new year's resolution of losing...

Designed by Kirk von Rohr


WattzOn
alpha
Personalizing energy consumption.
LOGOUT
kirk22 11,537W
YOUR DATA
FORUMS
EED
BLOG
ABOUT
CONTACT
FOOD 963W
DRIVING 963W
FLYING 100,963W
STUFF 963W
HOUSING 963W
GOVERNMENT 3,003W
YOUR LIFE: 17,528W
COMPARE
You vs Average User
VISUALIZE YOUR ENERGY
As a wind turbine
SHARE
Send to a friend
GOVERNMENT 1,876W
FLYING 1,876W
HOUSING 1,876W
DRIVING 1,876W
FOOD 1,876W
STUFF 1,876W
EMBODIED ENERGY DATABASE
RECENTLY ADDED ITEMS
WOOD CHAIR
Oak
DESK CHAIR
Plastic, Fabric
IPHONE
Apple Cell Phone
DESK PHONE
Panasonic xlr456
QUEEN MATRESS
Sealy Posturepedic
QUEEN BOX SPRINGS
Sealy Posturepedic
AVERAGE USER'S ENERGY USAGE
6,357W
USERS AND THE WORLD.
SEE MORE USERS„
SAUL 15908W
JIM 15908W


NON-ACCOUNTED2960 W
OTHER 3 W
ROADS 330 W
STREETLIGHTS 4 W
NASA 1 W
JUSTICE 4 W
ENERGY 4 W
OTHER 4 W
HHS 1 W
GSA 2 W
GOV.VEHICLES 3 W
VETERANS-AFFAIRS 3 W
POSTAL-SERVICE 5 W
DEFENSE 100 W
WHITEGOODS 8 W
EDUCATION 340 W
FINANCE 60 W
HEALTHCARE 680 W
RECREATION 110 W
HOUSE 260 W
MISCSTUFF1000 W
BOOKS 130 W
TEXTILES 90 W
WASTEDISPOSAL 9 W
BIKES 6 W
WATER 160 W
TRANSPORTTOME 40 W
NEWS 180 W
ELECTRONICS 250 W
COMPUTERS 700 W
BOATS 50 W
INTERNET 70 W
CARS 560 W
WORKHEAT 200 W
WORKELECTRIC 410 W
AG. FERTILIZER 50 W
AG. FOSSILFUELS 80 W
AG. ELECTRIC 40 W
AG. PESTICIDES 10 W
COFFEE 20 W
BEER & WINE 60 W
SUGAR 20 W
CEREALS & GRAINS 10 W
FRUIT, VEG & NUTS 90 W
DAIRY 50 W
FATS AND OILS 30 W
MEAT & EGGS 160 W
OTHER ELEC 8 W
LIGHTS ELEC 70 W
STEREO ELEC 1 W
LAPTOP ELEC 1 W
COMPUTER ELEC 10 W
FRIDGE ELEC 30 W
HEATING GAS 400 W
COOKING GAS 30 W
SHOWERS GAS 70 W
TAXIORRENTAL 470 W
TOYOTA TACOMA 240 W
DODGE SPRINTER 100 W
TOYOTA HILUX 160 W
DUNE BUGGY VW 150 W
HONDA INSIGHT 310 W
OAK-SFO 280 W
SFO-OAK 280 W
DR-SFO 310 W
SFO-DR 310 W
SFO-SYD1140 W
VIJ-SJC 280 W
SJC-VIJ 280 W
SJO-SJC 230 W
SJC-SJO 230 W
JFK-SFO 200 W
SFO-JFK 200 W
ORD-SFO 140 W
BOS-ORD 70 W
SFO-BOS 210 W
BUR-OAK 20 W
OAK-BUR 20 W
JFK-SFO 200 W
SFO-JFK 200 W
QUE-DTW-SFO 210 W
OAK-ORD-MON-QUE 210 W
DC-OAK 180 W
OAK-DC 180 W
BOS-SFO 210 W
SFO-BOS 210 W
OAK-OGG-HON-OAK 560 W
HEL-AMS-ATL-SFO 570 W
SFO-ATL-CPH 510 W
ATL-SFO 160 W
SFO-ATL 160 W
LHR-SFO 410 W
SFO TO LHR 410 W


State-level energy consumption per Capita, 2006 (kW)
KiloWatts
Average = 11.14kW
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
Alaska
Wyoming
Louisiana
North Dakota
Texas
Kentucky
Alabama
West Virginia
Indiana
Montana
Oklahoma
Mississippi
Arkansas
Iowa
South Carolina
Kansas
Tennessee
Nebraska
Minnesota
Delaware
New Mexico
Idaho
Maine
South Dakota
Ohio
Georgia
Virginia
Missouri
Wisconsin
Washington
Pennsylvania
Illinois
Nevada
Utah
Oregon
New Jersey
District of Columbia
North Carolina
Colorado
Michigan
Vermont
Hawaii
Maryland
Florida
Arizona
Connecticut
New Hampshire
California
Massachusetts
New York
Rhode Island
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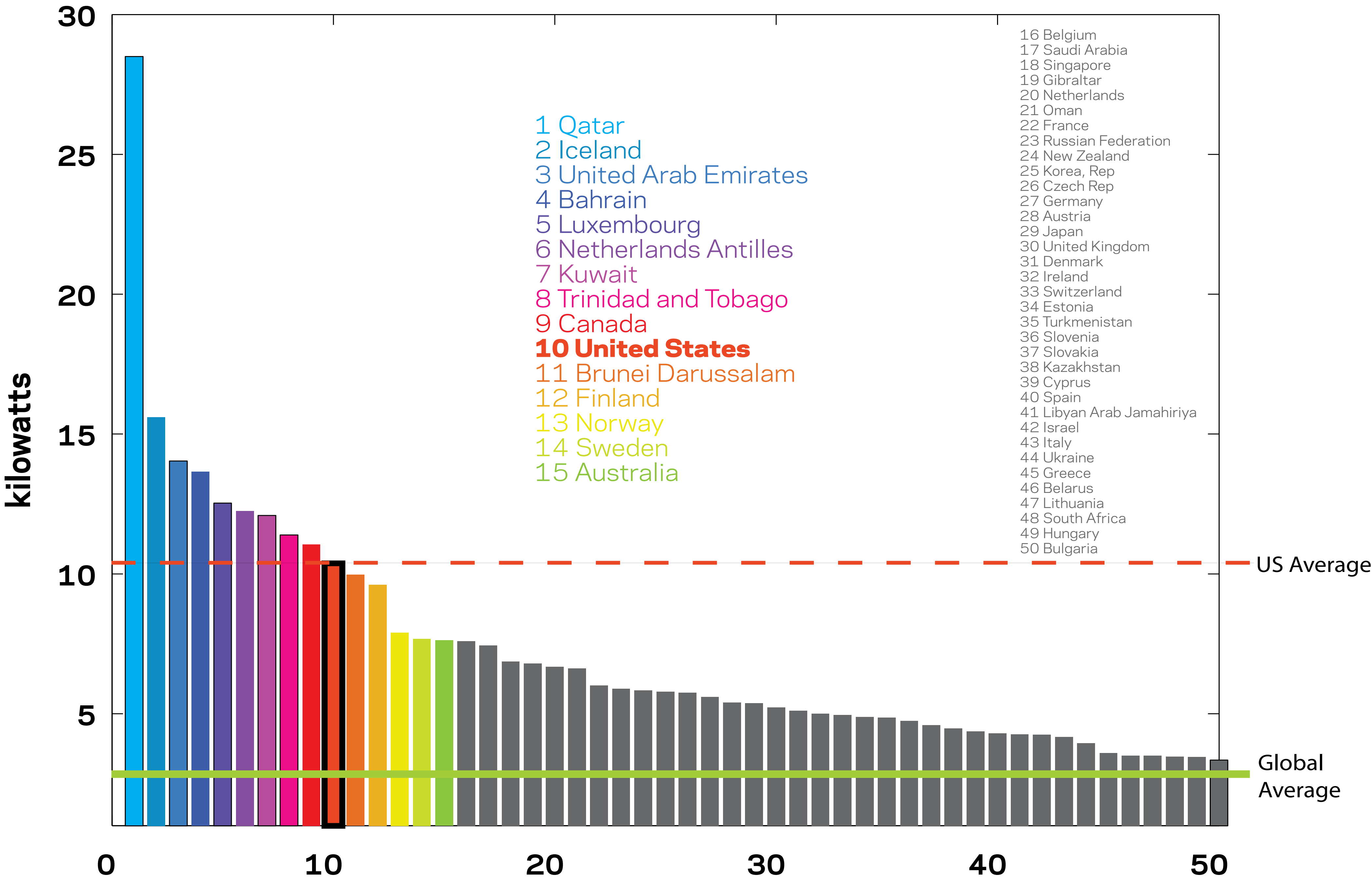
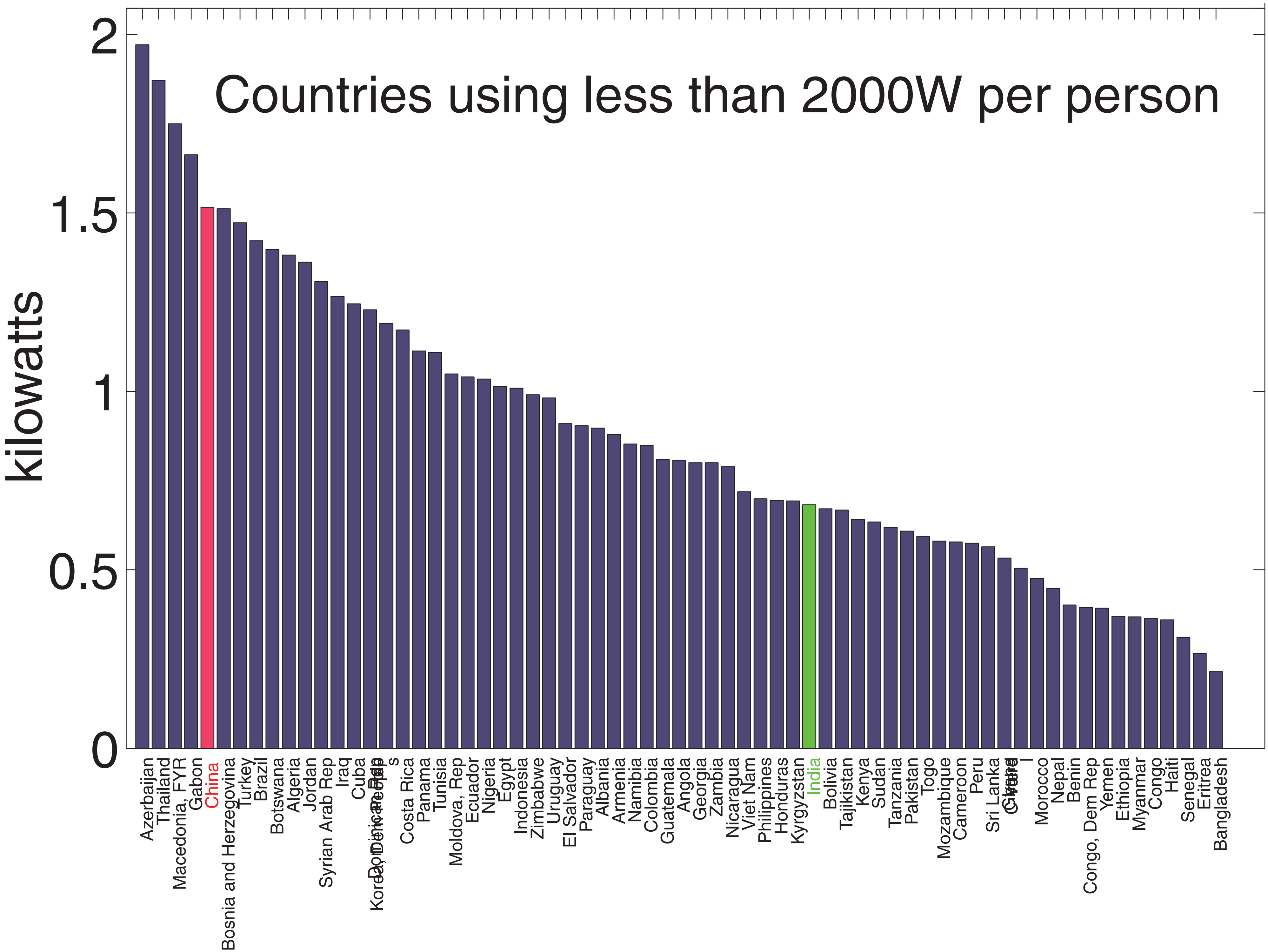
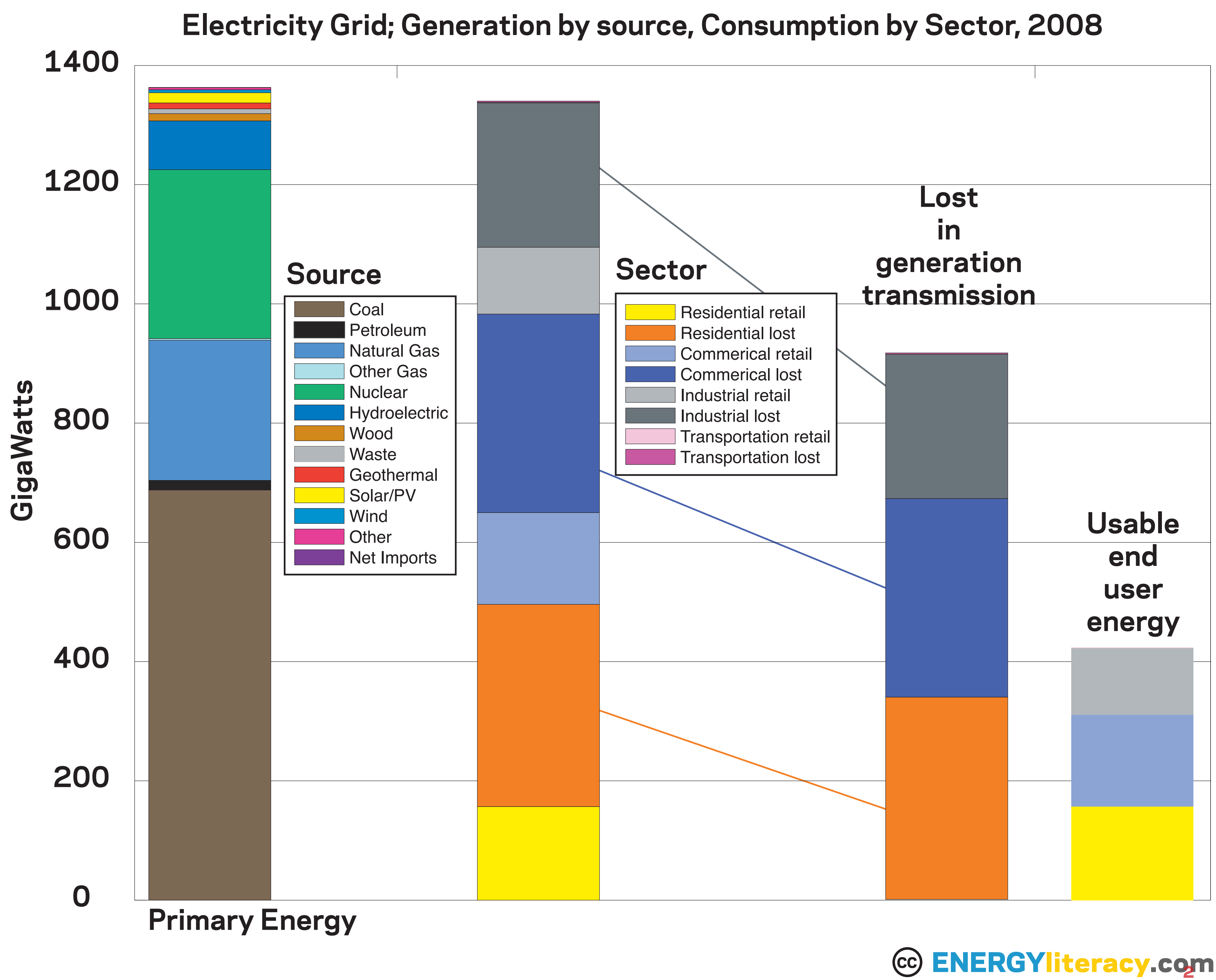
Per capita power use 2003




Countries using less than 2000W per person
kilowatts
0
0.5
1
1.5
2
Azerbaijan
Thailand
Macedonia, FYR
Gabon
China
Bosnia and Herzegovina
Turkey
Brazil
Botswana
Algeria
Jordan
Syrian Arab Rep
Iraq
Cuba
Costa Rica
Panama
Tunisia
Moldova, Rep
Ecuador
Nigeria
Egypt
Indonesia
Zimbabwe
Uruguay
El Salvador
Paraguay
Albania
Armenia
Namibia
Colombia
Guatemala
Angola
Georgia
Zambia
Nicaragua
Viet Nam
Philippines
Honduras
Kyrgyzstan
India
Bolivia
Tajikistan
Kenya
Sudan
Tanzania
Pakistan
Togo
Mozambique
Cameroon
Peru
Sri Lanka
Morocco
Nepal
Benin
Congo, Dem Rep
Yemen
Ethiopia
Myanmar
Congo
Haiti
Senegal
Eritrea
Bangladesh



Electricity Grid; Generation by source, Consumption by Sector, 2008
1400
1200
1000
800
600
400
200
0
GigaWatts
Primary Energy
Source
Coal
Petroleum
Natural Gas
Other Gas
Nuclear
Hydroelectric
Wood
Waste
Geothermal
Solar/PV
Wind
Other
Net Imports
Sector
Residential retail
Residential lost
Commerical retail
Commerical lost
Industrial retail
Industrial lost
Transportation retail
Transportation lost
Lost in generation transmission
Usable end user energy
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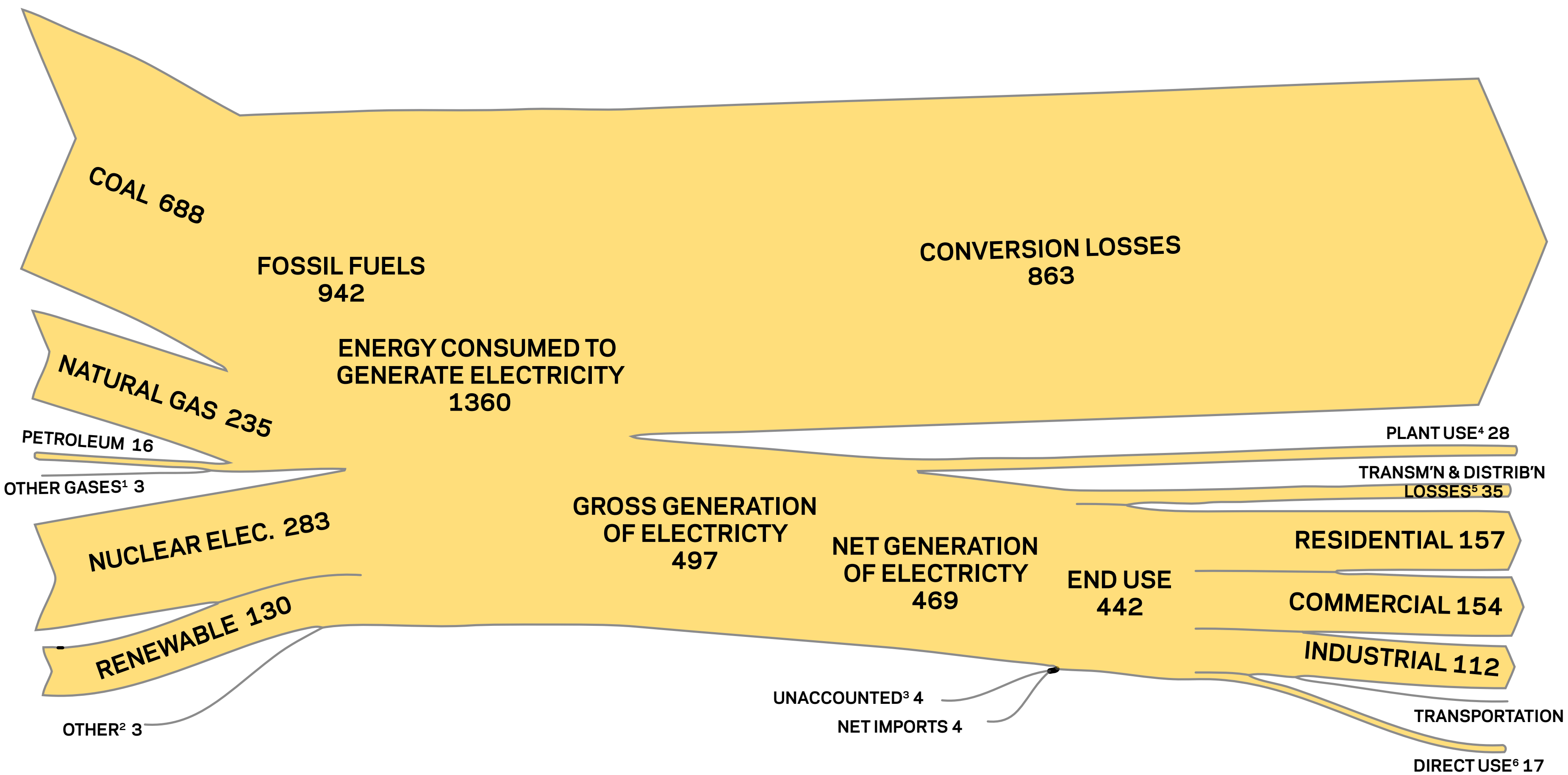
US Electricity Flow, 2008
(GW)



[1] Blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels.

[2] Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, miscellaneous technologies, and non-renewable waste (municipal solid waste from non-biogenic sources, and tire-derived fuels).

[3] Data collection frame differences and nonsampling error. Derived for the diagram by subtracting the "T & D Losses" estimate from "T & D Losses and Unaccounted for" derived from Table 8.1.

[4] Electric energy used in the operation of power plants.

[5] Transmission and distribution losses (electricity losses that occur between the point of generation and delivery to the customer) are estimated as 7 percent of gross generation.

[6] Use of electricity that is 1) self-generated, 2) produced by either the same entity that consumes the power or an affiliate, and 3) used in direct support of a service or industrial process located within the same facility or group of facilities that house the generating equipment. Direct use is exclusive of station use.

Notes: ▪ Data are preliminary. ▪ See Note, "Electrical System Energy Losses," at the end of Section 2. ▪ Values are derived from source data prior to rounding for publication. ▪ Totals may not equal sum of components due to independent rounding.

Sources: Tables 8.1, 8.4a, 8.9, A6 (column 4), and Energy Information Administration, Form EIA-923, "Power Plant Operations Report."

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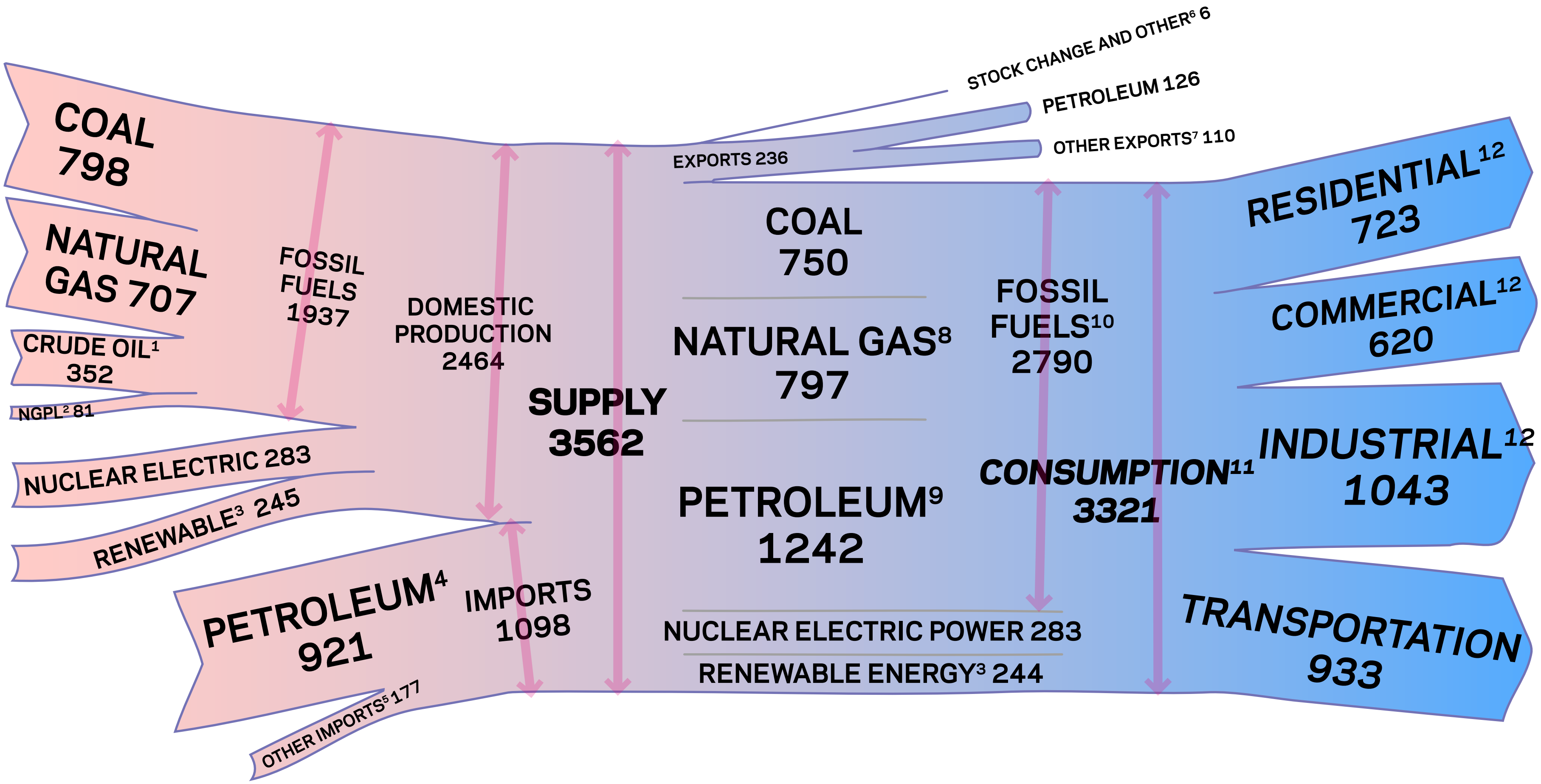
US TOTAL Energy Flow, 2008
(Gigawatts)



[1] Includes lease condensate.
[2] Natural gas plant liquids.
[3] Conventional hydroelectric power, biomass, geothermal, solar/photovoltaic, and wind.
[4] Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve.
[5] Natural gas, coal, coal coke, fuel ethanol, and electricity.
[6] Adjustments, losses, and unaccounted for.
[7] Coal, natural gas, coal coke, and electricity.
[8] Natural gas only; excludes supplemental gaseous fuels.
[9] Petroleum products, including natural gas plant liquids, and crude oil burned as fuel.
[10] Includes 0.04 quadrillion Btu of coal coke net imports.
[11] Includes 0.11 quadrillion Btu of electricity net imports.
[12] Primary consumption, electricity retail sales, and electrical system energy losses, which are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note, "Electrical Systems Energy Losses," at end of Section 2.

Notes: • Data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 1.1, 1.2, 1.3, 1.4, and 2.1a.

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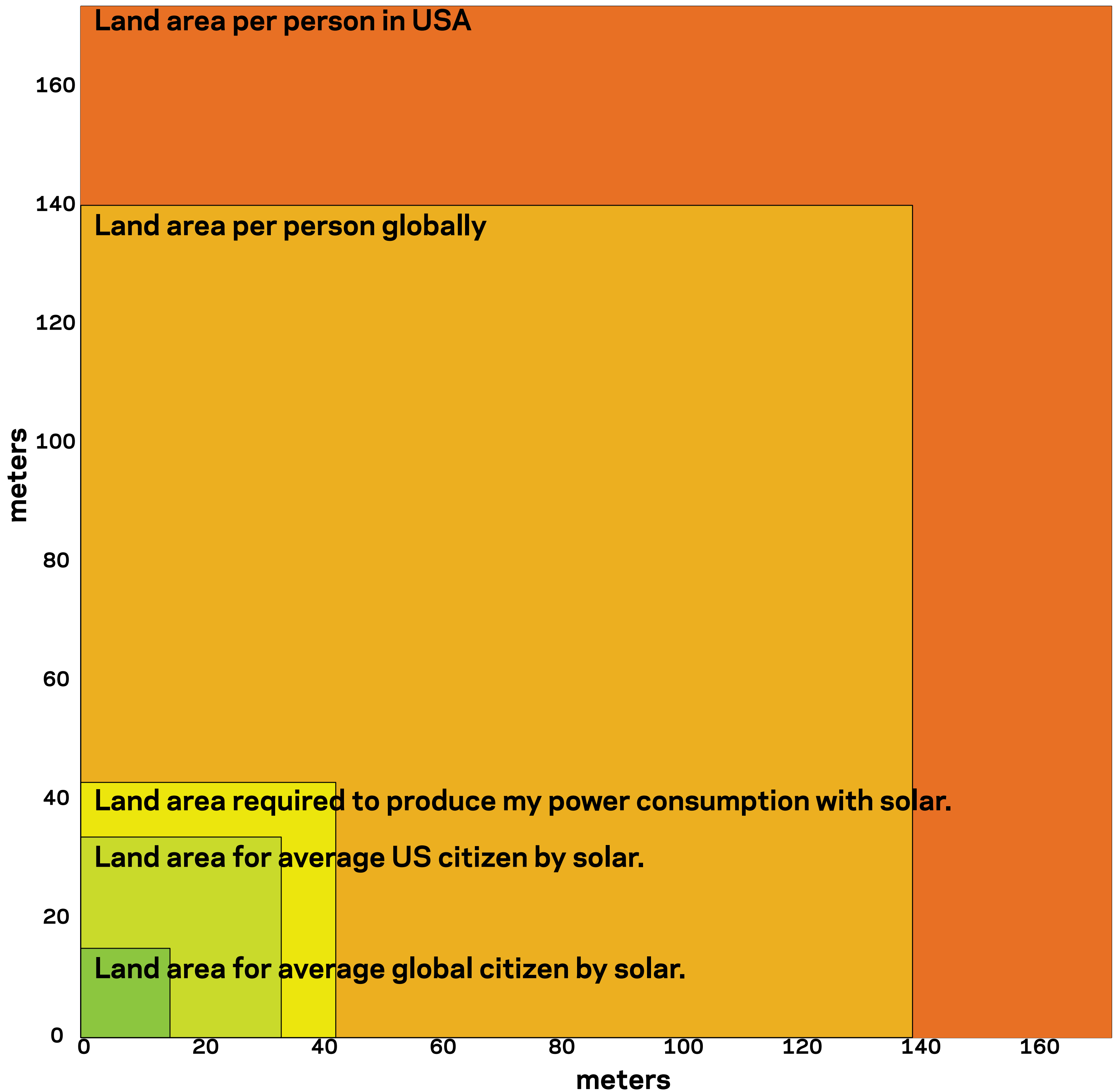
Land area per person in USA
Land area per person globally
Land area required to produce my power consumption with solar.
Land area for average US citizen by solar.
Land area for average global citizen by solar.
meters
meters
0
20
40
60
80
100
120
140
160

How can government enable success of clean tech and Smart Grid start-ups?

What should utilities and tech companies do to facilitate commercial success by viable clean tech and Smart Grid start-up companies?

Should utilities and tech companies actively provide venture capital funding to clean tech and Smart Grid start-ups?